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PHYSICO-CHEMICAL CONSIDERATIONS IN ASTROPHYSICS.*

BY

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AMONG the greatest advances which astrophysics has made in recent years, undoubtedly belong the apparently extremely reliable determination of the age of the earth, which has been arrived at on the basis of measurements by numerous investigators using the methods and theories of radio-activity. It is now regarded practically everywhere as certain that the production of the solid crust of the earth took place about sixteen hundred million years ago.

We make the following assumptions:

1. The earth was split off from the sun as a ball of fire of high temperature.

2. The Universe is in a stationary condition, that is, the present fixed stars cool continually and new ones are being formed.

So far as the first assumption is concerned, I cannot conceive that it can really be brought into question; all other assumptions, of whatever character, appear so extremely artificial that they, at least for the present, can scarcely be dis-

* Read by Dr. Irving Langmuir.

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cussed seriously. The second assumption appears at the outset to be wholly arbitrary and so it is to a certain degree but nevertheless it appears that hitherto every prominent investigator has accepted this assumption simply as an intellectual necessity. Moreover, I believe also that many proofs, if not of the correctness, yet at least of the usefulness of this assumption, have appeared.

By the aid of these two hypotheses we come to the following far reaching conclusions: the cooling of the highly heated yet fairly small earth must obviously have taken place quite rapidly so that the total age of the earth, i.e., the time which has elapsed since the separation of the earth from the sun, is likewise to be put at about sixteen hundred million years. The conjecture is a ready one, and previously has been generally made, that the formation of the planets came early in the life-history of the sun. Also on the basis of star data, one can regard this time as relatively short so that we finally arrive at the result that the age of the sun is to be put at scarcely more than two thousand million years. The demonstration just indicated is moreover nothing other than a direct application of our second hypothesis. The number of stars which are in the adolescent state, i.e., the "red giants," is known to be not very great; it therefore follows that the duration of this "state" can be only short.

We come now to the fundamental question, whence do the sun and the other fixed stars obtain the incredible amounts of energy which, during periods of time that are to be measured in thousands of millions of years, are sent out into the Universe in the form of radiation? Quite some time ago I showed that, if we are not willing to make highly fantastic hypotheses such as have been tentatively suggested by many astrophysicists, this source of energy must be sought for only in radio-active processes because these are the only ones which offer, even approximately, the amazing amounts of energy which come into play. But it may be asked whether even these are actually great enough and whether we can say anything concerning the kind of radio-active element involved.

Of the radio-active elements known to us, uranium comes first into consideration, but here a simple calculation shows that, even if the interior of the sun consisted predominantly

of uranium, which in itself would not be impossible, only about the half of the sun's energy could be supplied by this element through radio-active decomposition, especially through several thousands of millions of years. We recognize therefore that if, instead of uranium, we imagine an element which with equal radio-active development of heat, decomposes many times more rapidly than uranium, we should be able to explain satisfactorily the behavior of the sun with reference to its radiation of heat, at least in its present condition.

But now the following is to be observed: the sun is a fixed star which already has cooled off markedly: from star data, we conclude that the sun formerly must have radiated for a time about sixty times as much energy as at present. We recognize therefore that we must assume the coöperation not only of radio-active elements which decompose more rapidly than uranium but which at the same time must give up in the decomposition considerably more energy than uranium. I had therefore, at that time, surmized that the sources of the energy of the fixed stars must be looked for in radio-active elements which are of higher atomic weight than uranium.

The assumption that there are radio-active elements beside uranium, thorium, etc., which decompose more rapidly and in so doing also give off even greater amounts of energy, is not necessarily inherently fantastic; but one can indeed remain wholly skeptical with reference to such an *ad hoc* hypothesis. But when I set up this hypothesis, I could refer to a puzzling, extremely penetrating radiation, the Hess-Kolhoerster radiation, which is consonant with the conjecture that in the Universe such radio-active elements as we need must be present in incredible amounts.

Not much was known at that time of these radiations. I have therefore been eager to see that this remarkable radiation should be further investigated for, according to the considerations set forth for an understanding of the cosmos, this must be of the greatest significance.

The admirable works of Kolhoerster have proved definitely that we are concerned with a very much harder radiation, that is, one of shorter wave-length, than we meet with in the gamma radiations from the radio-active elements known to

us, whence it results with greater probability that there are in fact radio-active elements which are able to yield much more energy than those known to us. One may therefore well say that in recent years my hypothesis concerning the source of the energy of the sun and the fixed stars has received confirmation. It is time to seek by all suitable means this most important element in the earth also.

But there is another way than that mentioned above, that is, the isolation of one or more of these hypothetical elements, to make clear the nature of this wonderful cosmic radiation, and this other way should be of especial interest to The Franklin Institute, and I will therefore explain it briefly. We can designate the cosmic radiation as a very hard Roentgen radiation, and from the slight absorption of this radiation by matter we can make at least an approximate estimate of its hardness. The latter will be so much the greater, the higher is the potential difference by which the corresponding negative electrons need to be accelerated in a vacuum tube. We may estimate that from five to twenty million volts would be necessary for the artificial production of this cosmic radiation. In our laboratories we are as yet far short of producing such high potentials; but some years ago three young investigators, Messrs. A. Brasch, F. Lange and C. Urban, in my Berlin laboratory, hit upon the idea of repeating with modern apparatus the most famous of all meteorological experiments, namely, Franklin's.

In the neighborhood of Monte Generoso in Switzerland, i.e., in a region where thunder storms are frequent and violent, they have already been able, in the past years, to draw continuous sparks of about four meters length (corresponding to about two million volts) from a gigantic antenna, and it cannot well be doubted that yet much higher potentials can be made available for measurement and use. The above named young physicists are now occupied in repeating on a still greater scale Franklin's experiment; the problem in further investigations will then be to bring about, in addition to the breaking up of the atom, the production especially of cosmic radiation on our planet. Recalling the famous Latin verse which concerned Franklin, "Eripuit cœlo fulmen, sceptrumque tyrannis" one can unfortunately not forget that it is

scarcely less hazardous to tear the lightning from the heavens than the sceptre from tyrants; we shall therefore hope that the precautions contemplated by the young physicists will prove themselves efficacious with even the strongest lightning flash.

Evidently, the question as to the age of the sun and of the fixed stars is a fundamental problem for astrophysics. I have endeavored to find another way, and I indicated some time ago a method, which would permit us to reckon at least an upper limit with confidence. We know from Einstein that a body loses mass when it gives off energy; if the sun had shone for somewhat more than ten trillion years with the same brilliancy as today, its mass would have vanished into the universe in the form of a radiation. This period of time is therefore an upper limit to the age of the sun and we may immediately add that, since in the first place the sun in its earlier life radiated energy much more rapidly than it does today, and since in the second place, for many reasons, the amount of the mass which has vanished can scarcely form a very considerable portion of the total mass, the above indicated upper limit is much too high. The calculation just mentioned makes it therefore in the highest degree probable, indeed almost certain, that the age of the sun cannot amount to a hundred thousand million years. Certainly the superior limit thus determined is considerably greater than the value fixed by me above as the most probable, namely, two thousand million years. But on the other hand, we should be pleased to have the proof that the age of the sun must lie between two definitely given limits.

Perhaps the following consideration, which rests upon wholly different principles, is not altogether without interest. The "red giants" which are according to our conception stars whose age amounts apparently to only a quite small fraction of a thousand million years, have a very slight proper motion. We will assume that the sun, which it is known possesses at this time a velocity of about twenty kilometers per second, originated somewhere at a great distance from its present position and by a gradual increase of its velocity it has wandered into its present location. We might then in this manner ascribe to the sun, as a first approximation, the mean

velocity of ten kilometers per second, and we could then easily calculate that it, in the two thousand million years which we concede to it, has traversed a path of about one hundred thousand light years. It is not improbable that the sun at such a distance from its present-day position was formed by the agglomeration of more or less radio-active material, and even if this assumption cannot be regarded as a confirmation of the age of the sun figured out by me, yet one can at least say that the above result does not appear nonsensical.

In accordance with this conception, the sun, after an additional two thousand million years during which it will have become a red star of small luminosity, will have joined the numberless cold stars of our Milky Way which because of their distance and low luminosity are today invisible to us. But this result involves a difficulty which appears at once in the conception here portrayed and which I have felt forcibly; we must according to the principle of the stationary condition, meet with the distant cold stars incredibly more frequently than the fixed stars in the sole condition in which they are visible to us as hot glowing bodies, since the ordinary chemical elements are certainly extremely weakly radio-active and therefore decompose only extraordinarily slowly. But if, driven by forces which are wholly unknown to us at the time, the sun and the other stars pass over such orbits as we have calculated, the cool stars are so far removed from us that in spite of their extraordinarily great abundance we have no means of any sort of distinguishing them.

In conclusion, I may point out a few contradictions which exist between the principle of the stationary condition and the generally recognized requirements of physics and of physical chemistry.

In the first place, all natural processes take place finally in such fashion that existing difference of temperature always comes to a state of equality; and in the second place, the radio-active processes always occur as a disintegration, i.e., elements of high atomic weight decompose into those of lower.

The two phenomena become compatible with the principle of the stationary condition only if in some possible way a deviation, and one of even x large degree, occurs in the direc-

tion in which the above named natural processes are carried out. In other words, the investigator of Nature stands before the choice, either to relinquish the principle of the stationary condition, which above was characterized as an intellectual necessity, or to assume a possible continuous failure of the two above mentioned natural laws. In view of our considerations, we are naturally forced to follow the latter course.

In recent times the notion has been frequently expressed that the energy of radiation from the stars is produced by the combination of four hydrogen atoms to form one helium atom, in which indeed, according to Einstein's formula, a mighty evolution of heat must occur on account of the disappearance of mass which is involved. I cannot admit that this conception would be in any manner compatible with our known experience. Such processes as those indicated above, could take place only with incredibly high temperatures, such as we must regard, on the basis of our former knowledge of the cosmos, as never existing. Even in the interior of the hottest stars, no higher temperatures than about thirty millions of degrees could occur as Eddington has convincingly proven for otherwise the light pressure would cause the star to explode. But reactions between atomic nuclei bring into use wholly incredibly high temperatures as can be demonstrated with the highest probability, in different ways. The salvation of the principle of the constant state is not won with the assumption of the formation of the helium atom out of hydrogen atoms.

I may therefore hold fast to the hypothesis uttered by me that, just as the principle of the stationary condition of the cosmos demands that the radiation of the stars be absorbed by the luminiferous æther, so also finally the same thing happens with mass, and that, conversely, strongly active elements are continually being formed from the æther, though naturally not in amounts demonstrable to us, the radio-active disintegration of which maintains correspondingly the high differences of temperature which are observed in the Universe and which at the end form the driving force of all the processes of nature in the direction demanded by the second law of thermo-dynamics. This simple hypothesis would therefore restore to us the stationary condition of the cosmos.

Naturally, this hypothesis is not demonstrable in any manner directly; in any event, it may be indicated that "the wave theory of matter," this newest and most promising offspring of modern physics, lends to the processes demanded by my hypothesis a certain probability. But obviously one must be quite clear that such an hypothesis lays claim to nothing more than the expression of a logical possibility: the knowledge of the true inwardness of things lies yet in the remote distance.

Is there any purpose in forming at this time such a naturally uncertain hypothesis? I may answer this question by saying that it is ultimately a matter of taste. To me personally, an hypothesis which is as logical as may be, brings much even if it cannot lay any claim to great reliability, and I venture to believe that everyone who delves further into the described hypothesis will think likewise. Moreover, science is indeed rich in hypotheses which in passing exercise a considerable stimulating force even if later they have to be greatly modified. As examples, I might name the corpuscular emission theory of light in the realm of physics and the phlogiston theory of the chemist. Astrophysics, which on the one hand may claim for itself that it deals with the most interesting questions of physical research is, on the other hand, more than any other science, dependent upon daring hypotheses.

SOME EXPERIMENTAL EVIDENCE SUPPORTING THE KINETIC THEORY OF GRAVITATION.

BY

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SOME time ago I was advised by the Secretary that The Franklin Institute had honored me with the award of the Franklin Medal. This I esteem a very great distinction, of which I beg to express my deep appreciation.

The Medal was awarded for the pioneer development of the electric arc light, and the invention of the practical storage battery. The early development of the arc light was celebrated by the Institute last month, and I shall not treat of it further. But of the early history of the storage battery very little is known to the public, so I hope I may be pardoned for giving a brief statement of it.

The Planté secondary battery had long been known. This consisted of two lead plates immersed in dilute sulphuric acid. When an electric current was passed through the combination a very thin layer of peroxide of lead was formed on the surface of one plate while hydrogen gas was evolved on the other plate. After a time the charging current was reversed, resulting in reduction of the thin coating of lead peroxide to spongy metallic lead, and peroxidation of the surface of the other plate. Many more reversals of charging current were made at increasing intervals for several weeks or months, whereby a considerable coating of peroxide of lead was formed on one plate, and an equivalent coating of spongy metallic lead on the other plate. The capacity of such a storage battery cell was small and its cost prohibitive from a commercial standpoint.

It occurred to me that larger capacity and very much quicker preparation might be secured by initially coating the plates with a paste of lead oxide and sulphuric acid, which was found to adhere fairly well. The scheme proved quite

successful. This was in 1878. Later, the plates were made cellular, to receive a larger amount of the paste and hold it more firmly. A vast amount of experimental work followed. Patents were applied for in 1881, and after several years of interference litigation in the Patent Office, the famous patent No. 337,299 was issued March 2, 1886. It claimed "mechanically-applied active material or material adapted to become active." This exceedingly broad claim was afterward fully sustained by the Federal Courts, and controlled all practicable forms of storage batteries until expiration of the patent in 1903. Unfortunately for me, no great field of usefulness for the storage battery developed until after the fundamental patent had expired.

In the early nineties I retired completely from the electrical field of effort for the express purpose of gaining more available time for research in pure science. I have always keenly enjoyed hunting for new phenomena in physics and chemistry; and occasionally I have experienced the thrill of finding one, and the joy of investigating it.

But, fortunately perhaps, my research work has always been largely mixed with business affairs. In 1893 I helped organize and finance a company for the manufacture of portland cement, and have been one of its officers ever since. The company has been highly successful and profitable. About 1905 I organized "The Lindé Air Products Company" for the commercial manufacture of oxygen from the air. I was its president for several years until its business was firmly established. Then, finding it was taking far too much of my time, I negotiated a satisfactory arrangement with the Union Carbide Company whereby the latter took over the business management of the Lindé Company while I retained my large interests. The Lindé Company has now grown to very large proportions, and I am rather proud of it as one of my children.

In 1910 I had the honor to formulate and make public "A Kinetic Theory of Gravitation." [1] This has become known as the ether-wave, or energy-shadow theory. The only new postulate required by the theory is that some, or perhaps all, of the vast instrinsic energy of the ether exists in wave form of some sort capable of motive action on par-

[1] *Science*, March 10, 1911; *Nature*, March 23, 1911.

ticles, atoms or molecules of matter, and propagated in every conceivable direction so that the wave energy is isotropic. The waves are of such frequency, or otherwise of such character, that they pass through all bodies without obstruction other than that concerned in gravitation and a slight heating effect in some substances, and perhaps other slight effects. Distribution of the ether's energy is assumed to be uniform throughout the universe except as modified by the presence of matter.

The Kinetic Theory clearly indicates that the energy acquired by falling bodies is derived from the ether; and in subsequent papers I have submitted most convincing argument that this is true.

The Secretary has honored me with an invitation to make an address on the present occasion, on any subject I may select, preferably about some phase of my own research work; and I have chosen as my text "Some Experimental Evidence Supporting the Kinetic Theory of Gravitation."

Study of the nature of gravitation is beset with unusual difficulties, because gravitation is ever with us and about us; it is the one universal phenomenon, and we cannot escape from its influence—cannot obtain any outside point of view.

From the beginning of my experimental work on the problem of gravitation, many years ago, I have largely directed my efforts toward finding some evidence of the postulated ether waves other than gravitation itself; and it has seemed quite possible that such evidence might be furnished by a continual slight generation of heat within some substances specially adapted to exhibit it. The following argument will make this conception clear:

Heat is often defined as an agitation of atoms and molecules of matter, and measured by the total kinetic energy of such agitation. The agitation consists partly in internal vibrations of the elastic atoms and molecules and spinning about their various axes, and partly in a very rapid translatory motion among themselves. Thus they are supposed to dart about in every conceivable direction, constantly colliding with each other and rebounding or glancing in new directions. The kinetic energy of this translatory motion constitutes *sensible* heat (not total heat) and is the measure of *temperature*.

Anything (such as absorbed radiation) which stimulates the internal vibration of atoms or molecules likewise increases their translatory velocities by the increased violence of rebound after collision, and thus increases their temperature; and *vice versa*.

All the above is known to be true of gases and vapors (kinetic theory of gases), and is generally believed to be true of liquids and solids.

The "*mean* free path" and the "*mean* velocity" between collisions of the molecules of many gases under stated conditions have been computed. But it has also been shown mathematically that the higher and lower velocities, and the longer and shorter paths differ greatly from the means, and may in each respect vary twenty or more times in amount. Doubtless this is true also of liquids and solids.

From the fortuitously wide variation in velocities and free paths of the billions of vibrating atoms or molecules in their heterogeneous movement, it follows that collision frequencies must also vary greatly, from instant to instant, everywhere in a body of matter.

Probably the postulated gravitation waves are not confined to one frequency, but have a wide range of frequencies as do the well-known X-rays.

With the foregoing in mind it is easily conceivable that some kinds of matter may have atoms or simple molecules or complex molecules of occasional vibration frequency corresponding with some gravitation wave frequency, whereby fortuitous resonance can, for brief instants, be established at various points. This would result in a slight increase of vibrational activity and a cumulative rise of general temperature, perhaps sufficient to be detected.

A body of such matter, with some thermal insulation, would become and remain permanently warmer than a neighboring body similarly circumstanced, but not endowed, or less endowed with the permissive heat-generating quality.

The foregoing hypothesis had been my guide in a very lengthy search for some material exhibiting continual generation of heat in observable amount.

Two quite different calorimeters, very carefully designed and constructed, have been in frequent use for many years,

testing many metals and alloys, and also rocks and minerals for some slight and continuous generation of heat. Incidentally this research long ago led to the discovery of "spontaneous generation of heat in recently hardened steel," a new phenomenon, now well recognized in the metallurgy of steel.

The calorimeter work with rocks and minerals developed the fact that some of these substances do generate heat in easily observable amount, not due to radioactivity. The Bureau of Standards, with a calorimeter of its own design, is working with some of these minerals for the purpose of checking my findings.

It is notable that the materials which appear to be endowed with persistent heat generating activity are complex silicates; and it seemed highly probable that some silicates may be very much more active than others. This now appears to be true.

Guided by this thought I prepared and tested many artificial silicates. A silicate of the protoxides of nickel and cobalt showed very large activity, larger than either silicate alone; and this activity, after nearly two years aging of the silicate, appears to be permanent.

In the absence of other explanation, it has been thought that persistent generation of heat in some rocks and minerals, not due to radioactivity, is due to isotropic ether waves of great penetration; and in the light of more recent experiments, it is now thought that these ether waves are in the same class, perhaps having a wide range of frequency, with those postulated as the cause of gravitation.

Conversion into heat of some of the energy of the gravitation ether waves, however little, might be expected to impair, to some extent, the falling velocity of a heat generating substance; *and all such substances thus far tested have clearly shown impairment.*

I have yet found no exception to this remarkable phenomenon, though I have already tested many natural and artificial minerals. Substances which have shown no generation of heat in the calorimeters show no impairment of their falling velocity when compared with lead. Substances exhibiting small, moderate or large generation of heat have shown comparatively small, moderate or large impairment of

their gravitational acceleration. I aim to continue this research until the quantitative relationship of the two phenomena is ascertained. This may open a fertile field for mathematical exploration.

In making the above indicated comparisons of falling velocities I have largely used the method and apparatus described and illustrated in my 1923 paper on "Some New Experiments in Gravitation." [2] (See also 1924 paper of same title.) [3]

Two aluminum containers are used, alike in size, shape, weight and smoothness of surface, and dropped *simultaneously*, side by side through exactly the same distance (about 122 cm.).

Each container, at the end of its journey, breaks an electric circuit. But the breaks of both containers are in series in the same circuit, so that the break which occurs first produces a bright spark, while the belated break gives no spark because its circuit is already open.

When the containers are equally loaded with the same metal, there is no visible spark at either break or a very feeble spark at one or the other indifferently. But when they are equally loaded with certain different metals, one container persistently produces a bright spark, though the containers are always reversed in position for each trial. From this it seems clear that the container giving the spark falls a little faster than the other. This sparking condition is clearly manifested when the faster container reaches the end of its free path as little as .0125 mm. (.0005 inch) in advance of its neighbor. This indicates a time difference about 1/400,000 second.

To facilitate estimation of larger falling velocity differences I am perfecting a photographic method of observation. After falling about 110 cm. the small lower ends of the containers are photographed in silhouette against a white background having many horizontal black lines, and illuminated by a bright electric spark timed by allowing the conical shoulder of one container to contact with a fine, very flexible, steel wire. Duration of the spark is so brief, probably much

[2] *Proc. Am. Phil. Soc.*, Vol. LXII, No. 3, 1923.
[3] *Proc. Am. Phil. Soc.*, Vol. LXIII, No. 1, 1924.

less than a millionth of a second, that the container tips are practically stationary while being photographed.

After each exposure the right and left position of the containers is reversed and the photographic plate is so screened that only a horizontal strip is used at once. Thus eight exposures are made on one plate by suitably moving the plate-holder after each exposure.

In a recent experiment a marked container was filled with silicate of nickel and cobalt tightly packed; while the other container was loaded with an equal weight of lead sawdust (and cork) held firmly in cylindrical shape by a tightly fitting cork.

Each of the eight photographs on the same plate clearly showed the silicate container slower than its companion. Several more similar plates made with the same loaded containers all showed the same effect.

Of course I tried exchange of loads in the containers, but without observably affecting the result; the container holding the silicate was always slow.

The observed retardation of the silicate container must be due to impaired gravitational acceleration of the silicate as compared with the lead sawdust in the other container; and as the silicate constitutes only 30.8 per cent. of the total mass undergoing acceleration, we must multiply the observed retardation by 3.25 to find the full impairment of the silicate alone.

Micrometer measurements of the photographs will be made to find the quantitative value of retardation of the silicate.

Other materials tested by the photographic method have shown similar retardation in lesser degree.

Correlation of continual generation of heat in some substances and impairment of their gravitational acceleration, is regarded as very strong evidence in support of the kinetic theory of gravitation; and we seem now well started on the way of finding out something definite about the nature of gravitation, which is by far the greatest of all outstanding physical problems.

Electro-capillary Microphone. M. LATOUR. (*Comptes Rendus*, Jan. 23, 1928.) A capillary tube which is considerably wider above contains an electrolyte such as water to which an acid or a salt has been added. Its narrow part is sunk into a vessel of mercury. A layer of oil covers the electrolyte to prevent evaporation. Two wires run into the mercury and the electrolyte to secure good electrical contact. If a telephone receiver be connected between these two wires it reproduces sounds made some distance from the apparatus. The insertion of a capacity in the receiver circuit does not stop the emission of sound. This shows that there is in play an alternating electromotive force and not merely a direct current varied by changes of resistance. When an alternating E.M.F. of musical frequency is applied to the two wires the arrangement acts as a telephone receiver.

G. F. S.

The Speed of Waves in Radiotelegraphy. A. LAMBERT. (*Comptes Rendus*, March 12, 1928.) The speed of radio waves seems to be considerably below that of light. By the use of signals sent out from Honolulu and Saigon and observed at San Diego and Zikawei the greatest speed was obtained, viz.—293000 km./sec., while in another set it came out as small as 210000 km./sec. The mean value was 247000 km./sec.

G. F. S.

KERR EFFECT IN WATER DUE TO HIGH FREQUENCY RADIO WAVES.

BY

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Communication No. 26.

VARIOUS investigators who have measured the index of refraction of water for short radio waves, i.e., for wave-lengths between 300 and 3 cms. have found evidence of the existence of absorption lines in this region. Since it is phenomena of this type which render the measurements of the dielectric constant of aqueous salt solutions by high frequency bridge methods so uncertain, an investigation of these bands ought to be of considerable service in elucidating these difficulties. The existence of bands in this region would also help to explain the discrepancy existing between the value of the dielectric constant as calculated from the index of refraction and the intensity of infra-red band spectra and that given by direct experiment.

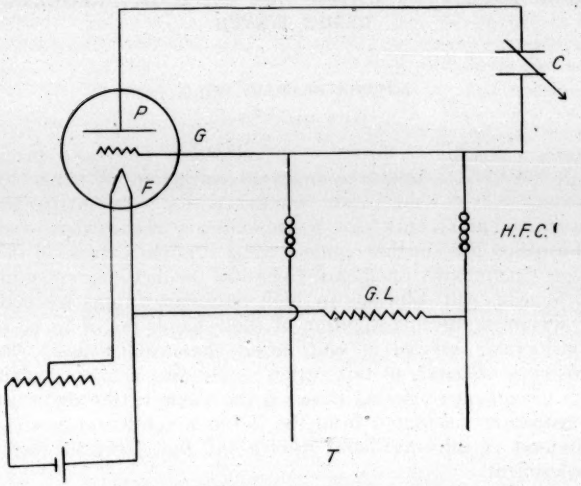
A diagrammatic sketch of the oscillator used in these experiments to produce the short electromagnetic waves is shown in figure 1.

The variable condenser *C*, shown in the above figure, which was used to adjust the frequency of the oscillations, had a capacity which could be varied from 400 cms. to 60 cms. In this work care should be taken that the oscillatory circuit be well insulated from ground, a satisfactory method being to mount the apparatus on a large glass plate, and also that all magnetic material such as transformers, etc., be at least 1 m. away from the circuit to avoid the induction effects of the high frequency waves.

The most accurate method which suggested itself for showing the existence of the electric spectrum of water, was one involving the measurement of the Kerr effect in water produced by the electromagnetic field of the oscillator. The

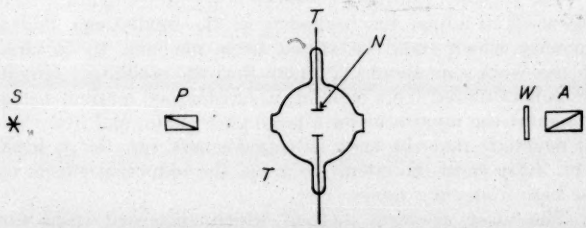
electric double refraction due to this field was measured for sodium light by the apparatus shown in Fig. 2.

FIG. 1.



P, *F* and *G*, the plate, filament and grid of the oscillator.
G.L., grid leak of 40,000 Ω.
H.F.C., high frequency choke.
T, transformer supplying 1,500 volts on the secondary.

FIG. 2.



This consists of a source *S*, a sodium gas burner, the Kerr tube *T* which was placed in parallel with the condenser *C* of Fig. 1 and contained two nickel plates placed parallel to the

axis of the tube and 1.6 cm. apart, and supported by tungsten leads sealed through the glass wall. The retardation was observed by means of the polarimeter, consisting of the analyzer A, the polarizing nickel P, and the quarter wave plate W. In the operation of this apparatus, light from the source S passed through the polarizing nickel P into the Kerr cell T along the axis of the tube between the plate electrodes and then through the analyzing system W and A.

Before we discuss the experimental results, however, we shall investigate the nature of the electric field in the cell T on the supposition that the medium in the cell, in this case water, has an absorption band within the range of the high frequency electric alternations applied to the cell plates.

If we let ν_s = the frequency corresponding to the center of the absorption band,
ν = the frequency of the electromagnetic waves produced by the oscillator,
E = the electric field intensity in the absorbing medium due to the high frequency alternating current of frequency ν,
and D = the electric induction,

then, according to Lorentz' theory of dispersion

$$D = \left[1 + \frac{\dfrac{\alpha}{\nu_s^2 - \nu^2}}{1 - \dfrac{\beta}{(\nu_s^2 - \nu^2)}} \right] \cdot E = \left[1 + \frac{\alpha}{\nu_s^2 - \nu^2 - \beta} \right] \cdot E,$$

where α and β are constants depending on the structure of the dispersive medium.

If we were to plot the values of D^2 against frequency ν for a constant value of E, we should find according to the above equation that as the frequency increased, the values of D^2 would increase from E^2 until it became infinite when

$$\nu_s^2 - \nu^2 = \beta,$$

then drop to zero when

$$\nu_s^2 - \nu^2 - \beta = -\alpha,$$

then increase again to infinity when

$$\nu_s^2 - \nu^2 = \beta,$$

and then decrease towards E^2 as ν was further increased.

If, however, we had taken into consideration the absorption of the radiation due to the resistance of the damping term, then we would have had a similar graph except that the value of D^2 would have approached a large maximum value instead of becoming infinite in the neighborhood of the absorption line.

From our knowledge of the electric field inside the medium, we are now in a position to consider the double refraction of the sodium light passing through the cell due to the applied electric oscillations.

According to the theory of the Kerr effect, the retardation δ, should be given by the equation

$$\delta = KD^2,$$

where κ is the specific retardation, i.e., the retardation for unit field intensity, and is connected with the wave-length λ of the light for which the double refraction is measured by the relation that

$$K = \frac{n_p - n_s}{\lambda},$$

where n_p and n_s are the refractive indices for light vibrating parallel and perpendicular respectively to the direction of the applied electric field.

The retardation of the elliptically polarized light should thus depend markedly on the relationship existing between the electric oscillations and the natural periods present in the refractive medium. Indeed, it should be zero at the position of any absorption line, then rise rapidly to a maximum on each side and then, as the frequency is still further increased or diminished from the position of the absorption frequency, it should decrease slowly towards zero.

THE ELECTRIC SPECTRUM OF WATER.

In the present experiments the maximum value of the oscillatory field E was less than 5 e.s.u. so that, if the medium were non-dispersive, we should not expect any observable effect on the application of the high frequency oscillatory

field, for we have from the measurements taken in electrostatic fields that

$$K = 4 \times 10^{-7},$$

so that the retardation in degrees is equal to

$$180 \times 25 \times 4 \times 10^{-7} = 1.8 \times 10^{-3}$$

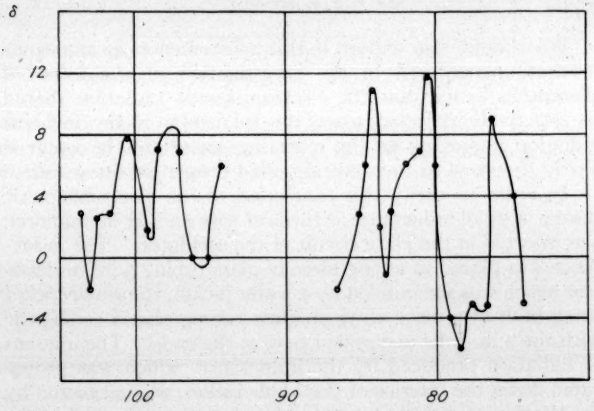
for

$$E = 5 \text{ e.s.u.},$$

a quantity which is far too small to observe.

The observed retardations δ plotted against frequency are shown in Fig. 3. The two different sets of readings, shown there, were taken for two different size cells in order to show that the effect did not depend on the constants of the circuit.

FIG. 3.



The ordinates represent the retardation, the abscissa, the wave number $\times 10^{-4}$.

These two cells had plates of the same area but the distance between them was in the ratio of 3 to 2, so that, if the periodic character of the retardation as a function of the frequency, Fig. 3, were due to the vibration of the cell itself with a characteristic vibration and with its overtones depending on its

capacity, the periodicity of the two different sets of observations out to be in the ratio of $\sqrt{2}$ to $\sqrt{3}$, an effect, however, which is not observed.

If the retardation due to the Kerr effect were proportional to the square of the electric intensity rather than to the square of the electric induction, then as we have seen from the calculation given in the preceding paragraph, the effect would not only have been too small to observe but also we would have been unable to account for the periodicity of the retardation as a function of the frequency.

Thus from these measurements we see that the retardation is proportional to the square of the electric induction and that the medium, water, has a number of absorption lines in this region which are equally spaced on a frequency scale, the constant difference $\Delta\nu$ between the different lines being

$$\Delta\nu = 4 \times 10^6 \text{ cm.}^{-1}.$$

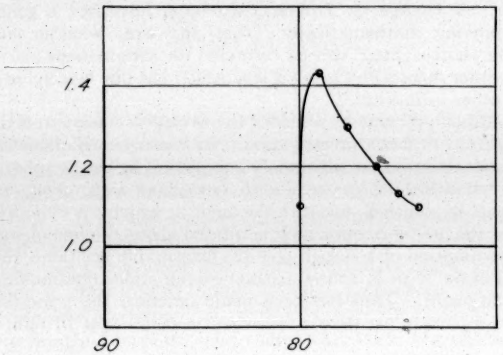
We should also expect if this phenomenon is analogous to that encountered in the investigation of the infra-red absorption bands that the electromagnetic radiation should be selectively reflected when the frequency of the incident radiation impinging on the reflecting surface of the water is nearly the same as the natural period present in the water.

In order to verify this conclusion of the electromagnetic theory, a small inductance, 2 turns of wire on a $2\frac{1}{2}$ in. mandrel, was inserted in the plate circuit of the oscillator. The inductance was placed in a long piece of glass tubing 3 in. in diameter which was surrounded by a water jacket, the water jacket being built of a piece of $3\frac{1}{2}$ in. glass tubing placed concentric with the 3 in. tube and sealed to it at the ends. The amount of radiation produced by the inductance, which was propagated down the interior of the water jacket, was measured by the heating of a thermo-couple placed at the open end of the glass tubing. The ratio of the amount of radiation measured by the thermo-couple when the water jacket was filled with water to that measured when the jacket contained no water, is given for the various frequencies comprising one absorption band in the accompanying diagram.

This diagram of the reflecting power versus frequency

gives a graph of the type encountered in the investigation of the infra-red residual rays. The reflecting power increases rapidly as the frequency is decreased towards that of the

FIG. 4.



The ordinates represent the reflecting power, the abscissa, the wave number $\times 10^{-4}$.

absorption line, reaching a maximum in its vicinity, and then decreases gradually on the other side of the line as the frequency is still further decreased.

The Correction of Astigmatism. T. J. I. BROMWICH. (*Nature*, May 12, 1928.) Sir George Airy while holding the Lucasian professorship at the University of Cambridge, 1826–28, was the first to use cylindrical lenses to remedy astigmatism. He had this kind of lenses ground for the benefit of his own vision. A later Lucasian professor, Sir George G. Stokes, 1849–1903, furnished a general theory proving mathematically "that any eye (whether long-sighted or short-sighted) can be corrected for astigmatism (as well as these other defects) by using a lens which has one face spherical and the other cylindrical."

The author proceeds to consider the saving of money and time resulting from Stokes's investigation. In consequence of his conclusions an oculist is now adequately equipped if he has 60 spherical and 40 cylindrical lenses each with one plane side, along with instruments by which to measure the angle at which the cylindrical lens gives the best correction as it is rotated about the line of sight. On the assumption of 100 such possible measurable positions, there is a total of $60 \times 40 \times 100 = 240{,}000$ combinations obtainable by the simple outfit. Thus has been made practical the prescribing of a million pairs of astigmatic lenses per year in Great Britain.

G. F. S.

SCHROT-EFFECT IN HIGH-FREQUENCY CIRCUITS.

BY

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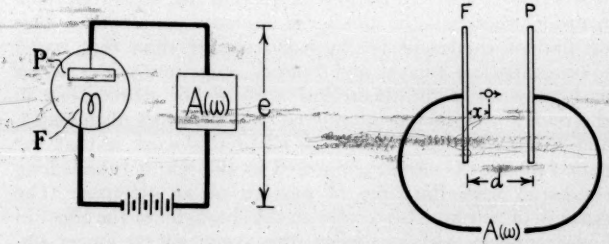
In 1918 W. Schottky predicted theoretically that in an electrical circuit connected to a thermionic tube there would be fortuitous fluctuations of current due to the fact that the thermionic current is not continuous but is carried by discrete charges. Schottky's view of the phenomenon was a statistical one in which the behaviour and disturbance due to the individual electrons were lost. An alternative view which furnishes a clearer and more detailed picture is obtained by tracing the consequences of the passage of a single electron from filament to plate, and then to arrive at statistical values by assuming these individual processes to be random in time. Thus if the circuit connected to the tube comprises an inductance coil and condenser in parallel, the transfer of charge will excite characteristic oscillations in this circuit, and if the impacts are completely at random it follows from Rayleigh's theorem that the long-time-average of the voltage (or current) will be statistically equal to n times that due to one electron transfer, where n is the number of electrons per second. This method of treatment is physically clearer than that based upon statistical theory and Fourier-series analysis. So far as I know all of the theoretical work on the schrot-effect in thermionic circuits has considered only the gross phenomena, and the assumption underlying all of this work is that the period of the LC-circuit connected to the schrot tube is long compared with the time of passage of an electron. The purpose of this note is to indicate the character of the effect in high-frequency circuits, when this condition no longer obtains and a microscopic view of the electron's flight must be taken.

1. **Experimental Results.** — The gross equations of Schottky, with Johnson's numerical correction, have been ver-

ified by Hull and Williams,[1] and by Williams and Vincent,[2] for electronic conduction. In the first case the frequency region was about 7.5×10^5 pps (400 meters), and in the second case of the order of 5×10^4 pps (6000 meters). J. B. Johnson,[3] working in the low-frequency range of 8–6000 pps, obtained results which were discordant with the theory, the effects being higher than expected. Johnson and Schottky have endeavored to explain these low-frequency results as a "flicker" effect. At the other end of the spectrum I had made, prior to these publications, some previously unreported experiments with electrons at frequencies of the order of $1.5–5 \times 10^7$ pps (20–60 meters) and had obtained results which were consistently low by about 2–3 per cent. In this region the experimental difficulties are considerable; nevertheless the above deviation is thought to be within the error of experiment. I have also measured the effect with positive emission from a tungsten filament in an atmosphere of cæsium and found important discrepancies at quite moderate frequencies in the radio region. The following theoretical investigation originated in an attempt to account for these low values.

2. **Microscopic Theory of the Schrot-Effect.**—With reference to Fig. 1, which shows a thermionic tube connected to an electric circuit having an admittance $A(\omega)$, we wish to calculate the time-average of the square of the voltage (e^2)

FIG. 1.



Thermionic tube connected to electrical circuit of admittance $A(\omega)$ for generation of schrot-noise.

[1] A. W. Hull and N. H. Williams, *Phys. Rev.*, **25**, 154, 1925.

[2] N. H. Williams and H. B. Vincent, *Phys. Rev.*, **28**, 1250, 1926.

[3] J. B. Johnson, *Phys. Rev.*, **26**, 71, 1925.

produced across the terminals of this circuit by the passage of *one electron* from the cathode F to the positively charged plate P, both of these electrodes being plane and of infinite extent. This result is most simply arrived at by the Rayleigh-Schuster [4] method of analyzing the e^2 *qua* ω distribution by means of the Fourier-integral.

As the electron moves from the cathode to the anode it induces variable charges on these electrodes. The exact relation between these charges and the position of the electron may be calculated [5] but this is not easy and it does not seem worth while to bother about it in view of the difficulty of the end-effects and other geometrical discrepancies in any practical device. As a first approximation it will be assumed that the relation is a linear one. Denoting the surface charges at cathode and anode by q_F and q_P:

$$q_F = -\frac{x}{d}\epsilon - \frac{EA}{4\pi d},$$
$$q_P = -\frac{x}{d}\epsilon + \frac{EA}{4\pi d}, \qquad (1)$$

where A is the area of the part of the infinite structure under consideration and E is the potential difference between the electrodes. The second term on the right will be recognized as the *geometrical capacity* between the electrodes, and may be denoted by C_0. It may be remarked that this is not the whole capacity when there is a thermionic current in the tube limited by space-charge, but is augmented by an extra capacity effect due to the gross motion of the statistical space-charge. This "electron capacity" can be calculated and measured and a discussion of it is undertaken in a separate paper. I was originally led to look for it as the result of some mathematical work in 1920 following a remark of Prof. P. W. Bridgman. Hartmann noticed something of the kind, although his value of 180 micromicrofarads appears to

[4] See Rayleigh, *Phil. Mag.*, **27**, 466, 1889.
A. Schuster, *Phil. Mag.*, **37**, 509, 1894, or "Theory of Optics," p. 339, 2d Ed. (London: 1909).

[5] This calculation is facilitated by the work of O. Emersleben, *Ann. der Phys.*, **82**, 713, 1927.

be 100-fold too large; but Hull (*loc. cit.*, p. 158, footnote) failed to detect it, due I suppose to the fact of his working with currents limited by temperature, under which condition the electronic capacity theoretically vanishes. It would in any case be important only for very high frequencies.

The total current to the electrodes, including the normal or stationary thermionic current, corresponding to (1) is:

$$\frac{dq}{dt} = \frac{\epsilon}{d} v(t) + C_0 \frac{dE}{dt} + g_0 E, \tag{2}$$

where g_0 is the first-order conductance of the thermionic path $= di/dE$. This current flows through the external circuit of symbolic admittance $A(d/dt)$, hence:

$$A(d/dt) + g_0 E + C_0 \frac{dE}{dt} = -\frac{\epsilon}{d} v(t) = I(t). \tag{3}$$

The term on the right, in which $v(t)$ represents the electron velocity *qua* function of t, may be regarded as an *impressed current*, and if desired E may be found by a straight-forward solution of this equation. This, however, is tedious and unnecessary since we merely require E^2 and not $E(t)$, and this may be found directly from the frequency distribution of $i^2(t)$ by Rayleigh's theorem.[6] $I^2(t)$ can in turn be found by means of the Fourier-integral. In the form in which we shall use it this theorem may be stated as follows:

RAYLEIGH-SCHUSTER THEOREM.

Let two quantities $Q_1(t)$ and $Q_2(t)$, satisfying conditions, be related by means of a linear (differential) equation, Q_1 being of the nature of an effect (dependent variable) resulting from the "impressed" quantity Q_2; let $A(i\omega)$, the so-called transfer-admittance, be defined as the relation between Q_1 and Q_2 when Q_2 is of the form $Exp\, i\omega t$, thus $Q_1(t) = |A(\omega)|\, Exp\, i[\omega t + \varphi(\omega)]$. Then:

[6] This important theorem was called to my attention in 1920 by Prof. E. C. Kemble, in connection with the analysis of the distribution of energy in atmospheric disturbances. Somewhat similar applications to electrical problems have been made by J. R. Carson, "Electrical Circuit Theory and Operational Calculus," p. 185 (New York, 1926). It will be noticed that what Carson designates as his "corollary to Rayleigh's theorem" is simply Schuster's theorem (*loc. cit.*, p. 339).

$$\int_0^\infty Q_1(t)^2 dt = \frac{1}{\pi}\int_0^\infty |A(\omega)|^2 Q_2(\omega)^2 \cdot d\omega \qquad (4)$$

where

$$Q_2(\omega)^2 = \left[\int_{-\infty}^{\infty} Q_2(t)\cos \omega t \cdot dt\right]^2 + \left[\int_{-\infty}^{\infty} Q_2(t)\sin \omega t \cdot dt\right]^2. \qquad (5)$$

and if $Q_2(t)$ represents a disturbance recurring at random intervals at the average rate of n times per second, then:

$$\overline{Q_1(t)^2} = n\int_0^\infty Q_1(t)^2 \cdot dt = \frac{n}{\pi}\int_0^\infty Q_1(\omega)^2 \cdot d\omega, \qquad (6)$$

or in other words the frequency distribution of the square of the total disturbance is equal to n times that of a single disturbance, and is of precisely the same form qua ω.

The application of this theorem in calculating the schrot-effect is as follows: Let $A(\omega)$ represent the transfer-admittance between the impressed current in (3) and the voltage across the terminals of the electrical circuit associated with the tube and denote by $A_a(\omega)$ the transmission factor of the amplifier generally used to produce measurable voltages. Then:

$$\overline{E(t)^2} = \frac{n}{\pi}\int_0^\infty |A(\omega)|^2 I(\omega)^2 \cdot d\omega, \qquad (7)$$

or at the output terminals of the amplifier whose input is connected across E:

$$\overline{E_0(t)^2} = \frac{n}{\pi}\int_0^\infty |A(\omega)|^2 \cdot |A_a(\omega)|^2 I(\omega)^2 \cdot d\omega. \qquad (8)$$

If the variation of $A(\omega)^2 \cdot I(\omega)^2$ over the transmission band of the amplifier is sufficiently small compared with that of $A_a(\omega)$, then this quantity may be taken out of the integral sign and

$$\overline{E_0^2} = \frac{n}{\pi}|A(\omega)|^2 I(\omega)^2 \int_0^\infty |A_a(\omega)|^2 d\omega. \qquad (9)$$

The integral quantity may be readily determined experimentally and is simply the area under the transmission-squared curve. In order to realize the simplicity of (9) the schrot-circuit should be untuned, e.g. of the nature of a resis-

tance with the tube capacity in parallel as suggested by Williams and Vincent. In the case originally contemplated by Schottky, and used by Hartmann, Williams and Hull, and Johnson the schrot-circuit comprised an antiresonant LC combination and in this case the more difficult form (8) must be employed. Leaving aside further reference to specific circuit details the quantity $nI(\omega)^2$, which will be here called the *schrot-function*, will be more specifically considered.

3. **Temperature-limited Thermionic Current.**—The frequency distribution of $nI(\omega)^2$ may be calculated by means of eq. (5). For saturation current: $v = \epsilon E_p t/md$ $(0 < t < \tau)$, where E_p is the steady accelerating voltage across the tube and τ is the time of passage of the electron from cathode to anode. The impressed current occurring in (3) is:

$$I(t) = 2\epsilon t/\tau^2, \tag{10}$$

hence:

$$\begin{aligned} nI(\omega)^2 &= \frac{4\epsilon^2 n}{\tau^4}\left\{\left[\int_0^\tau t\cos\omega t\cdot dt\right]^2+\left[\int_0^\tau t\sin\omega t\cdot dt\right]^2\right\} \\ &= \frac{4\epsilon^2 n}{\omega^4\tau^4}\{2(1-\cos\omega\tau)+\omega^2\tau^2-2\omega\tau\sin\omega\tau\} \qquad (11) \\ &= n\epsilon^2\left\{1-\frac{(\omega\tau)^2}{18}+\frac{(\omega\tau)^4}{720}-\frac{(\omega\tau)^6}{50{,}400}+\cdots\right\} \\ &= I_s\epsilon f(\omega\tau), \end{aligned}$$

where I_s represents the average thermionic current.

As $\omega\tau$ becomes vanishingly small $f(\omega\tau)$ approaches the constant value $I_s\epsilon$ calculated by Schottky; in the general case there is a departure from the Schottky theory which increases with the frequency. The above function $f(\omega\tau)$, computed by Lt. Raymond Asserson, is shown in Fig. 2 for values of $\omega\tau$ up to 2π.

As to numerical magnitudes: For electrons,

$$\tau = d\left(\frac{2m}{E_p\epsilon}\right)^{\frac{1}{2}} = 3.4\times 10^{-8}\frac{d}{\sqrt{E_p}}, \quad \text{(sec, volt, cm)}. \tag{12}$$

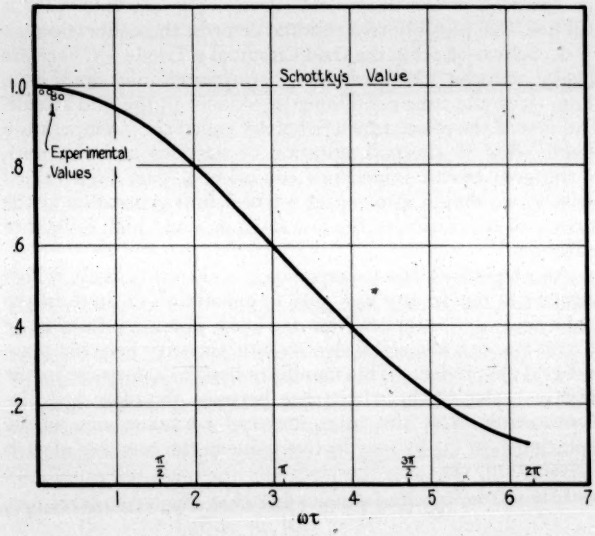
If $d = 0.6$ cm. and $E_p = 100$ v, τ will be equal to 1.7×10^{-9} sec. For a one per cent. decrease in the schrot-effect from

the low frequency, or Schottky, value, $\omega\tau = 0.425$; a sharply tuned LC circuit would have to be tuned to a frequency of $\omega/2\pi = 4 \times 10^7$, or 7.5 meters wave-length. For positives from cæsium, with which I have made some measurements,

$$\tau = 1.66 \times 10^{-5} d/\sqrt{E_p}$$

and under the above experimental conditions, $\tau = 8.5 \times 10^{-7}$ sec. In this case a one per cent. decrease from the Schottky

FIG. 2.



Values of the schrot-function for high frequencies showing departure from Schottky's value and experimental values obtained by the author.

value would be obtained at a frequency of 8×10^4, or 3760 meters wave-length. Also since the voltage at which saturation (temperature limited) thermionic current is obtained varies with the temperature, the schrot-function decrease will set in at lower frequencies, the lower the temperature. This assumes that E_p is adjusted to a value just sufficient for saturation. It

would appear that the conditions favorable to experimental detection of this effect would be low cathode temperature and large electrode areas. Under more usual conditions its incipience would involve frequencies considerably higher than those at present employed for technical purposes. At these frequencies and voltages the finite mobilities of the electrons might demand a revision of the amplifier theory.

The experimental values obtained by me at high frequencies for electrons and positive ions from cæsium are shown by the circles in Fig. 2. These values show a drift in the direction of the theoretical curve. The absolute value is still low, due possibly to a residual error in the calibration.

4. **Schrot-effect in the Grid Circuit of a Triode.**—There are several ways in which random disturbances may occur in a three electrode tube containing impedance in the grid circuit. The first is the effect which Schottky called the "temperature effect," due to thermal agitation of the ions and electrons. If the grid circuit impedance comprises a pure high-valued resistor, we should also expect a true schrot generation at the surface of separation of the low resistance and high resistance materials.

Another effect due to impedance in the grid circuit, which however is not in any way due to generation of noise in the grid circuit *per se*, arises from feedback of energy from plate to grid through the small electrostatic capacity between plate and grid electrodes. This manifests itself in a decrease in the effective value of the admittance between the plate and filament terminals of the tube, and can be taken care of by replacing g_0 in (3) by its effective value in the presence of such regeneration, viz.:

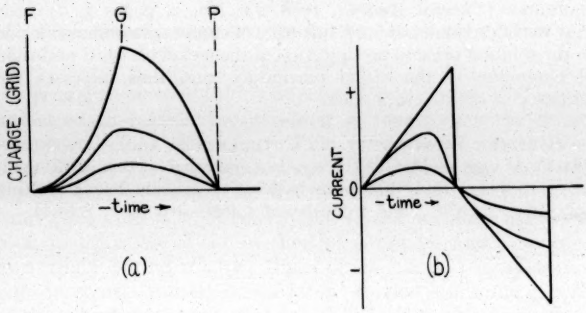
$$g_0' = g_0\left(1 + i\frac{\mu\omega C_m}{A_g + i\omega C_m}\right), \tag{13}$$

where C_m is the grid-plate capacity, A_g the admittance between grid and filament and μ the amplification factor of the triode.

Still another effect is that due to the charges induced upon the grid by the electrons passing through its meshes on their way to the plate (grid being polarized so as to eliminate actual current to it). This may be calculated by

the method of the preceding section, the induced charges being first calculated from the geometry of the tube, and the "impressed" current being then analyzed for frequency distribution by eq. (5). Without attempting to reproduce this work here, Fig. 3 illustrates in a rough way (*a*) the charge

FIG. 3.



Schrot-effect in grid circuit of a triode. (*a*) charge induced upon grid by electrons passing at various minimum distances from grid wires, and (*b*) current corresponding to this induced charge.

induced upon the grid and (*b*) the corresponding impressed current, due to electrons passing through the grid at various minimum distances from the wires. The uppermost curve represents the electrons which are reflected by the grid. As to the frequency distribution of this current-function, it will be clear that since the total induced charge is zero, the schrot-function will vanish at low frequencies, will increase with frequency and have maxima at $\omega\tau = n\pi/2$ (odd n), and minimum for even n. Since in the tube the divergence of the total current is zero, the change induced on the grid will affect the schrot-effect in the plate even though the grid impedance is zero. This shielding effect will vanish at low frequencies, but will modify the Fig. 2 schrot-function in a triode at high frequencies.

December 1927.

Quantitative Determination of Nickel in the Presence of Chromium. When alpha benzildioxime is added to the ammoniacal solution of a nickel salt, the nickel is precipitated quantitatively as the nickel derivative of the dioxime. However, if chromic salts are also present, they contaminate the precipitate even when tartrates or citrates have been added to the solution. FREDERICK G. GERMUTH of the Department of Public Works of Baltimore (*Chemist Analyst*, 1928, *17*, No. 2, pages 3, 7) finds that the addition of a minute quantity of cupric ammonium chloride to the solution prior to precipitation of the nickel prevents occlusion of chromium in the nickel precipitate, and thus increases the accuracy of the determination. J. S. H.

Hydrogen Peroxide. A. C. CUTHBERTSON, G. L. MATHESON AND O. MAASS of McGill University (*Jour. Am. Chem. Soc.*, 1928, *50*, 1120–1121) find that pure hydrogen peroxide has a melting point of — 0.89° C., and a density of 1.4649 at 0° C. J. S. H.

ON RELAXATION OF ELECTRIC FIELDS IN KERR CELLS AND APPARENT LAGS OF THE KERR EFFECT.

BY

J. W. BEAMS, PH.D. AND ERNEST O. LAWRENCE, PH.D.

INTRODUCTION.

WHEN an electric field is impressed between parallel plates immersed in carbon bisulphide it is found that the liquid becomes doubly refracting. This phenomenon, called the Kerr Effect, has been known for a long time and has been used in various ways in optical investigations involving very short time intervals. Recently one of the authors [1] made use of a modification of the method of Abraham and Lemoine [2] in a study of the relative times of appearance of spectrum lines in spark discharges and later [3] carried out some experiments which indicated that in some liquids the Kerr effect lags behind a rapidly changing electric field. During the past year the authors [4] studied the photo-electric effects produced by short flashes of light and also investigated in further detail the apparent lags of the Kerr effect in various liquids. The present work is a continuation of these experiments.

EXPERIMENTAL ARRANGEMENT AND THEORY OF THE METHOD.

The experimental arrangement for the study of lags in the Kerr effect and for the production of short light flashes centers around two Kerr cells, K_1 and K_2, placed between crossed Nicol prisms, N_1 and N_2. The normals to the surfaces of the plates of one cell are at right angles to the normals to the surfaces of the other pair of plates and both sets of normals make angles of forty-five degrees with the electric vector of the plane polarized light passing between the plates from N_1.

[1] Beams, *Phys. Rev.*, Vol. 28, p. 475, 1926.

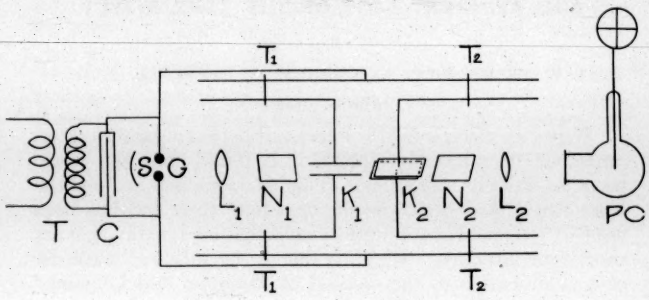
[2] Abraham and Lemoine, *Comp. Rend.*, Vol. 130, p. 245 (1900).

[3] Beams and Allison, *Phil. Mag.*, Vol. 3, p. 1199, 1927.

[4] Lawrence and Beams, *Proc. Nat'l. Acad.*, Vol. 13, p. 207 (1927). Beams and Lawrence, *Proc. Nat'l. Acad.*, Vol. 13, p. 505 (1927).

As the diagram indicates, (Fig. 1), the plates are attached to the spark gap SG by wires of variable length T_1T_2, the spark gap being also the source of light for the Nicol prism-Kerr cell optical system.

FIG. 1.



Prior to the discharge of the spark the potential difference applied across the spark gap by the transformer T and condenser C is also impressed across K_1 and K_2. Being at right angles to each other, however, the ellipticity of the light produced by the double refraction in K_1 is compensated by the opposite double refraction in K_2 and therefore the light emerges from K_2 plane polarized and unable to pass through N_2. On discharge of the spark a steep discharge wave is propagated along the wires and at a time after the beginning of the spark discharge equal to the wire path divided by the velocity of light the cells begin their discharge. Thus, for example, if the leads to K_2 are longer than the leads to K_1, K_1 will begin discharging before K_2 and during the period when the fields between the plates are unequal the light will be elliptically polarized and a portion of the light from N_1 will emerge from N_2.

The intensity of the light emerging from the Nicol N_2 is a function of the differences of the birefringence in the two cells and, indeed, because of the small values actually operative in the present experiments, the intensity of the light is proportional to the square of the differences in the retardations of the electric vector. The double refraction being

proportional to the square of the electric field between the cell plates, it follows that the intensity of the light I is

$$I = I_0(V_1^2 - V_2^2)^2,$$

where V_1 and V_2 are the voltages across K_1 and K_2 at any time t and I_0 is the proportionality constant which of course depends on such factors as the Kerr constant of the liquids, the size of the Kerr cells, the intensity of the light entering N_1, etc.

In order to obtain a qualitative theory of the action of the electro-optical arrangement it is assumed that the electric field between the Kerr cell plates disappears exponentially in time after the discharge wave strikes the cell. Thus, if the leads to the Kerr cells differ in length by l cms. such that K_1 begins its relaxation of the electric field at time t_1 and K_2 at a corresponding time $t_2 + t_l$, where $t_l = l/c$, c being the velocity of light, the intensity of the light emerging from N_2 at any time prior to t_1 will be zero (for the cells are arranged so that each shall compensate the effects of the other when both are charged to the same voltage) and in the time interval t_1 to $t_1 + t_l$ the intensity will be

$$I_{t_1}^{t_1+t_l} = I_0 V^4(1 - e^{-2\alpha_1 t})^2,$$

and for all values of t greater than $t_1 + t_l$ the intensity of the transmitted light will be proportional to

$$I_{t_1+t_l}^{\infty} = I_0 V_0^4(e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2,$$

where of course α_1 and α_2 are the exponential time constants which determine the rapidity of relaxation of the electric field in K_1 and K_2, respectively.

The total flux of light energy through N_2 consequently is

$$E = E_0 \int_{t_1}^{t_1+t_l} (1 - e^{-2\alpha_1 t})^2 dt + E_0 \int_{t_1+t_l}^{\infty} (e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2 dt,$$

which reduces on integration to

$$E = E_0 \left[t_l + \frac{\alpha_2}{(\alpha_1 + \alpha_2)\alpha_1} e^{-2\alpha_1 t_l} + \frac{\alpha_1 - 3\alpha_2}{4\alpha_1\alpha_2} \right]. \qquad (1)$$

If the Kerr cells are identical in shape and are placed symmetrically with respect to other parts of the electrical circuit their time rates of discharge are equal, i.e.,

$$\alpha_1 = \alpha_2 = \alpha.$$

For such a special case, equ. (1) reduces to

$$E = E_0 \left[t_l + \frac{1}{2\alpha} (e^{-2\alpha t_l} - 1) \right]. \tag{2}$$

Clearly for $t_l = 0$, that is, when the wires connecting the cells to the spark gap are of the same length the birefringence in the two cells compensate for all time and the flux of light from N_2 is zero.

It is equally evident from equation (1) that in case $\alpha_1 > \alpha_2$ the flux of energy from N_2 is not zero when $t_l = 0$ and indeed the energy flux is not even a minimum. The value of t_l for which E is a minimum is of course the value which satisfies the condition,

$$\frac{dE}{dt_l} = 0$$

and is

$$t_m = \frac{1}{2\alpha_1} \log \left(\frac{2\alpha_2}{\alpha_2 + \alpha_2} \right). \tag{3}$$

Thus, if the voltages across the plates of the Kerr cells decrease exponentially at different rates typified by the constants α_1 and α_2, the maximum extinction of the light is attained when the wire paths to the two cells are unequal by the amount l cms. where

$$l = ct_m.$$

Substituting this value of t_m in equ. (1) we have an expression for the magnitude of the flux of energy through the shutter when the wire paths are arranged to give greatest extinction, viz.,

$$E_m = \frac{1}{2\alpha_1} \left[\log \left(\frac{2\alpha_2}{\alpha_1 + \alpha_2} \right) + \frac{\alpha_1 - 3\alpha_2}{2\alpha_2} + 1 \right]. \tag{4}$$

It is easy to see, moreover, that different rates of discharge of the Kerr cells irrespective of the mode of discharge, would always be in evidence by such lack of complete extinction of the light through the optical system.

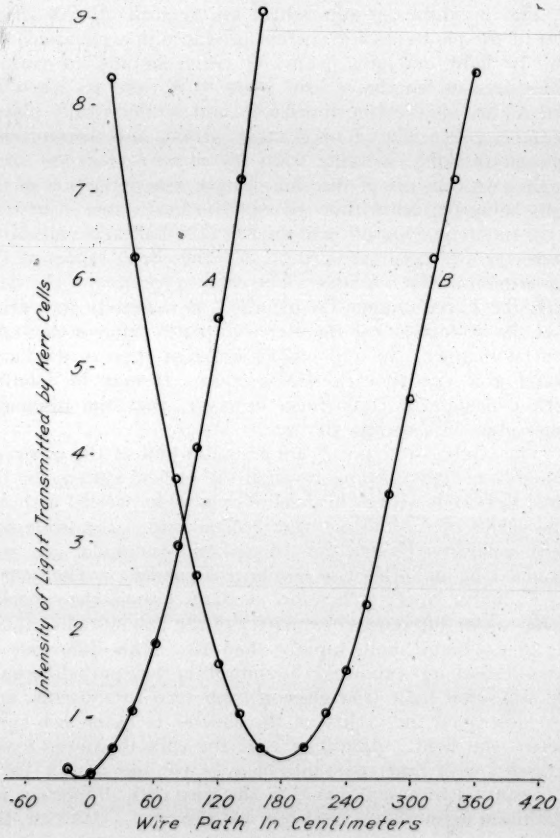
EXPERIMENTAL OBSERVATIONS.

Fig. 2 exhibits results which are typical. Curve A is a plot of the photo-electric current produced in a photo-cell PC due to light emerging from N_2 corresponding to various differences of lengths of lead wires to K_1 and K_2 when K_1 and K_2 are identical in dimensions and symmetrically placed in the circuit. The photo-electric current, and therefore the amount of light emerging from N_2, is zero when the wires to the two cells are of the same length, the extinction of the light being perfect within the experimental error. Curve A is the theoretical variation of the flux of radiation as calculated from equ. (2) assuming α to be 10^8; the circles represent the experimental observations. The close agreement of the data with the curve cannot be regarded as definitely indicating that the voltage across the Kerr cell plates drops in an exponential manner; an appreciably different type of discharge would give rise to very similar data. It may be inferred with considerable confidence, however, that the discharge takes place in less than 10^{-8} sec.

The circles of Curve B are a similar plot of the observed amounts of light passing through the optical system for the same Kerr cells with a third cell K_3 placed in parallel with K_2. The plates of K_1 and K_2 were 8 cms. long, 1 cm. wide and were separated by 0.5 cm. of carbon bisulphide. K_3 was 15 cms. long and otherwise similar to K_1 and K_2. The system K_2 K_3 had a capacity therefore of about 3 times the capacity of K_1. The differences of capacity of the two systems caused K_1 to discharge more rapidly than K_2. This difference of rates of discharge produced the shift of the wire path difference for minimum light transmission from zero to 180 cms. and also destroyed the ability of the shutter to extinguish completely the light. Assuming that the cells discharge exponentially with time constants of $\alpha_1 = 10^8$ and $\alpha_2 = \frac{1}{3} \cdot 10^8$ it is computed from equ. (3) that the wire path differences for maximum extinction is the observed 180 cms. However, the

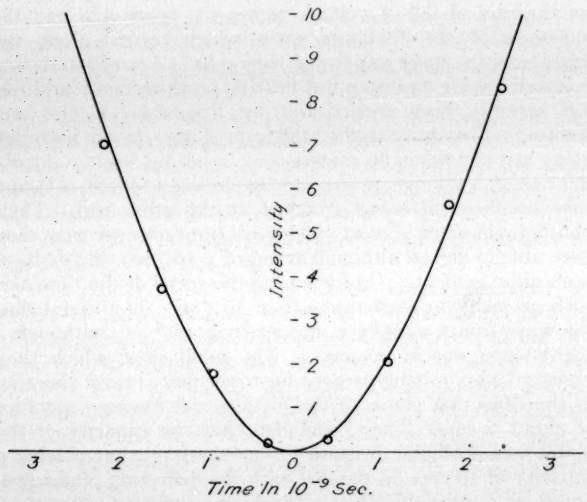
variation of the flux of light through the optical system with different relative wire paths to K_1 and K_2 is very much different from the variation to be expected from equation (1). Indeed, the minimum flux of light is less than a tenth of the

FIG. 2.



amount predicted by equ. (4). It appears therefore that an exponential discharge cannot account quantitatively for the action of the Kerr cells. The fact that there are very marked shifts of relative wire paths for maximum extinction of the light, the light extinction nevertheless being so nearly complete, indicates that the discharge is less rapid initially and more rapid in its later stages.

FIG. 3.



The dependence of the rate of discharge on the capacity of the cells suggested that cells of smaller capacities would yield much more rapid relaxations of the birefringence. Cells having plates 2 cms. long with otherwise similar dimensions to the 8 cms. cells gave the data of Fig. 3 where the curve is the theoretical curve, [equ. (2)] with $\alpha = 2 \cdot 10^8$ and the circles represent the experimental observations. Also, inserting correspondingly small capacities in parallel with the cells gave rise to differences of wire paths to the two cells for extinction of the light which interpreted by equ. (3) indicated

such larger values of α and therefore more rapid decay of the double refraction. However, the change in α with change in capacity was not linear and seemed to approach a limiting value for cells of these dimensions.

DISCUSSION.

The way in which the Kerr cells discharge clearly depends not only on their capacities and the inductance and resistance (resistance being negligible) of the connecting wires but also on the rate of fall of voltage across the spark gap and the steepness of the discharge wave which travels along the wires from the spark gap to the Kerr cells. A very interesting research having an important bearing on these considerations has recently been carried out by Rogowski, Flegler and Tamm.[5] They have studied the form of wave fronts traveling along parallel wires 60 meters long resulting from suddenly impressing a voltage at one end by closing a switch, a Braun tube oscillograph being attached at the other end. Their photographs show in most cases wave fronts steeper than they were able to detect, although slopes of $3 \cdot 10^{-8}$ sec. should have been quite evident. On increasing the speed of the time axis such as easily to resolve less than 10^{-8} sec. they found that the wave fronts were even steeper than 10^{-8} sec., although a slight slope was in evidence. The small slope which they observed was probably largely due to the finite rate of charging of the deflecting plates of the oscillograph having capacities of about 6 cms. They concluded that the capacity of the plates was negligible because it was observed that placing a capacity of 10 cms. in parallel with the deflecting plates produced no appreciable change in observed effects. However, this test was carried out using a slower time axis which was incapable of resolving effects of 10^{-8} sec. duration. Even with the slower time axis a very marked effect was produced when plates of 20 cms. capacity were inserted in parallel with the deflecting plates, the magnitude of the effect being such as to make it quite evident that the capacity of the oscillograph determined the steepest observed slopes. Their very fine technique led also to a study of the time of break down of spark

[5] Rogowski, Flegler and Tamm, *Archiv. für Elektrotechnik*, Vol. 18, p. 479 (1927).

gaps. They found that the voltage across a spark gap drops to a small value in less than 10^{-8} sec. even when the platinum points of the spark gap were 6 cms. apart.

The general conclusion to be gained from their research therefore is that the wave fronts traveling down the wires in the present experiments had slopes extending over less than 10^{-8} sec. and consequently that the inductance of the lead wires and the capacity of the Kerr cells determined largely the nature of the fall of voltage across the plates. If the effect of resistance of the lead wires were large compared to the effect of their inductance the voltage would have dropped exponentially as has been assumed above in the theory of the action of the optical system. A simple computation shows, however, that the resistance of the wires was negligible and therefore the discharge, instead of falling off exponentially, because of the inductance, was less rapid initially and more rapid in its later stage. As pointed out in an earlier paragraph this estimate of the nature of the discharge is in accord with a reasonable interpretation of the experimental data of curve *B*, Fig. 2.

In a study of the photo-electric effects produced by flashes of light emerging from the electro-optical shutter corresponding to various differences of wire paths to the two cells, it was concluded that flashes as short as 10^{-10} sec. duration were produced. In view of the present definite evidence for the very appreciable discharge rates the former conclusion must be modified. The shortest flashes produced were more probably of the order of magnitude of 10^{-9} sec. duration.

Experimental observations in the past which have been interpreted as evidence of a lag of the Kerr effect behind the electric field are, on the basis of the present work, more probably due merely to the different capacities of cells containing dissimilar liquids having various dielectric constants.

In 1913 Gutton [6] carried out some experiments which were interpreted as indicative of very considerable lags of the Kerr effect in various liquids. He arranged two Kerr cells with their plates at right angles to each other between crossed

[6] Gutton, *Jour. d. Phys.*, Vol. 3, p. 445 (1913).

nicols and adjusted the distance apart of one of the pairs of plates so that the Kerr effects produced in each cell were compensated, thereby extinguishing the light observed through the crossed nicol. He found that, with different liquids in the two cells, although their Kerr effects compensated for equal applied static voltages, extinction of the light was not attained when sufficiently high frequency alternating voltages were used. He found it necessary to increase the field in one of the cells by a readjustment of the separation of the plates in order to regain extinction. This was interpreted as indicating that the Kerr effect in one of the liquids was unable to build up as rapidly as the changing electric field and therefore required a larger capacity, i.e., greater electric field to produce sufficient birefringence to compensate the double refraction in the other cell. It is more probable that the cell of larger capacity did not charge up to the same potential as the smaller cell and for this reason alone compensation was not attained at high frequencies.

The two cells containing different liquids when adjusted to compensate each other with equal static potential differences across the pairs of plates will have capacities proportional to the ratio of the dielectric constant to the Kerr constant of the liquids. This is true because a large Kerr constant requires a small cell to produce a given birefringence and for given dimensions of the plates the capacity of course is proportional to the dielectric constant. It is to be expected therefore that a cell containing a liquid having a large value for this ratio would have a relatively slow charging and discharging rate and would apparently exhibit a lag of the Kerr effect relative to the Kerr effect in the other cell containing a liquid having a smaller value for this ratio. This is really what Gutton observed as the table below indicates.

Pairs of Liquids.	Ratio $\frac{\text{Dielectric constant}}{\text{Kerr constant}}$.	Lag of Kerr Effect.
Nitrobenzene	.0046	0.6 (10^{-8} sec.)
Bromonapthalene	.016	
Nitrobenzene	.0046	1.4 (10^{-8} sec.)
Carbonbisulphide	.026	
Carbonbisulphide	.026	1.7 (10^{-8} sec.)
Toluene	.10	

The first column lists the pairs of liquids examined, the second column records the ratios of the dielectric constant to the Kerr constants (which are proportional to the capacity of the cells containing the liquids) for the various liquids and the third column contains the observed apparent excess lag of the Kerr effect in the second liquid relative to a lag in the first. It is seen that in all cases the cell having the larger capacity contained the liquid exhibiting the larger apparent lag of the Kerr effect. Consequently, it is to be concluded that his observations cannot be regarded as measures of lags in the Kerr effect but are the results of capacity effects.

The observations in the past [3] using the technique involved in the present experiments which were interpreted as observations of lags of the Kerr effect are quite evidently also due to capacity effects. The extinction of the light passing through the optical system was so nearly perfect in experiments of this sort—although the rates of discharge were sufficiently different to require very marked differences in wire paths to the cells to obtain extinction—that a relative lag of the Kerr effect in one of the liquids presented itself as the most reasonable interpretation of the phenomenon. However, the present work makes such a view quite out of the question.

There is, therefore, at the present time no experimental evidence for the existence of a lag of the Kerr effect behind rapidly changing electric fields. This conclusion is quite in accord with prevailing theories of the Kerr effect which predict such lags to be considerably less than were detectable by any of the mentioned experiments.

SLOANE LABORATORY,
YALE UNIVERSITY,
June 12, 1928.

A New Art in Electric Lighting. W. E. BUSH. (*Electrician*, March 30, 1928.) To the Exposition des Arts Décoratifs held in Paris in 1925 can be traced the inception of a new movement in the production of illumination. Where fittings were used at all they were often made of frosted glass in flat sheets, but in many cases there were no fittings the arrangements for illumination having been built into the structure of the building. In London such lighting is used in the Café Royal, The Trocadero and elsewhere. A good application is on the "Ile de France" where most staterooms and saloons get their light from glass panels or hidden sources. There are but few suspended lighting fixtures on the vessel. "The magnificent dining saloon is flooded with light from moulded glass panels, slightly yellow tinted, which are let into the ceiling and upper walls. Behind each panel is fixed a 300 watt gas-filled lamp, and the intensity of illumination is so high that an impression of brilliant sunlight is created. The total lighting load for this room alone is 50 kilowatts. The lighting of some corridors is particularly interesting, where, instead of employing lamps totally concealed behind a cornice, narrow frosted glass strips are fixed along the wall at picture-rail height, and the lamps placed behind the glass. Even the cross in the beautiful chapel is of moulded glass lighted from behind."

In Paris the Galeries Lafayette have a canopy consisting of glass panels behind which are white and colored lamps. From a central switchboard color changes are produced that cause beautiful effects. The new type of lighting is in evidence elsewhere in Paris.

Thus a high total intensity of illumination is obtained with low brightness of the illuminating surface. This comes from the larger area of glass used in comparison with the usual types of lamp and from the employment of a larger number of lamps of moderate candle-power rather than a small number of high intensity. The new kind of illumination must be designed at the time of the planning of the building. It cannot be subsequently imposed as an afterthought. Its introduction may well mark the passing of the purely utilitarian conception of illumination and the substitution of artistic standards.

G. F. S.

EFFECT OF METHODS OF DEMAGNETIZATION ON THE ENERGY REQUIRED TO MAGNETIZE STEEL.

BY

JOHN D. BALL, B.S., E.E., Ph.D.

IT has been observed for a number of years that the hysteresis losses in magnetic materials have been indicated to be less when tested by means of alternating current than when tested by the direct current or step-by-step methods. For example, the hysteresis loop taken by the well-known means of measuring flux changes by a ballistic galvanometer frequently indicates more hysteresis loss than when the same specimen is tested by methods where the material is continually going through a cyclic state as in the separation method such as testing at various frequencies or by methods using slow cycles.

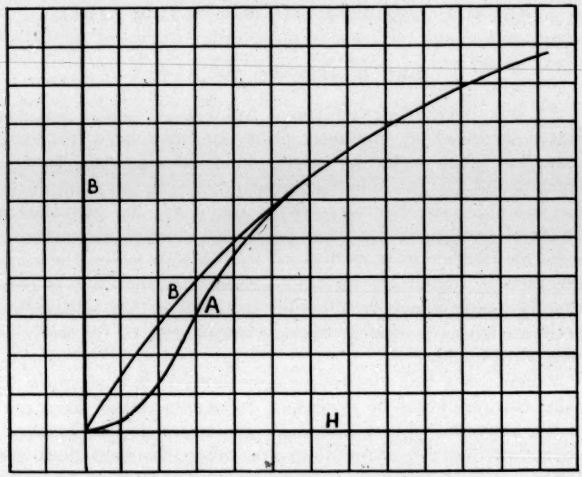
When using the step-by-step methods it is customary to make the observations necessary to obtain a half loop and let the other half be obtained by draftsmanship. However, when data for the entire loop are taken the loop does not always close at the top. Obviously many discrepancies are due to variations in the materials themselves and in the inaccuracies of testing, especially in such step-by-step methods which involve cumulative errors.

It is also a well-known fact that at low flux densities, when plotting B and H values, the resulting graph is a reverse curve with two decided bands. The curve shows that the increase of flux density with increasing field or applied magnetomotive force is not as rapid at the beginning of the magnetization as later on when the flux density increases very rapidly with increasing field until the further increase of flux density is curtailed by approaching saturation. This fact is illustrated in Fig. 1.

It is to be noted that at very low flux density the B–H curve does not show correspondingly low flux changes with increasing H as indicated by curve "B," but when a sufficient number of observations are taken the characteristic curve

of any magnetic material is such as indicated by curve "*A*," which is a typical *B*–*H* curve.

FIG. 1.



Curve *A*, typical *B*–*H* curve for a magnetic material. Curve *B*, *B*–*H* curve when flux is passing through zero at *H* = 0 from negative values of *B* and *H*.

Not long ago an explanation suggested itself that this first bend of curve "*A*" or, more definitely, the considerable field strength required to build up the flux density might be due to one, or both, of two things. First, the static inertia of magnetic elements involved might be such that a force must be expended to start the motion of the molecules or magnetons or what-not, in the same manner as energy is required to bring any body from rest to motion. After the motion is well under way further increases of *H* would result in a more rapid increase of flux values, or, to satisfy other theories of magnetism, a force would be required to change the velocity or direction of the elements involved. Another explanation is that the continuous motion of magnetic elements into different states or arrangements may be accomplished with less

energy than when the change of motion or state is brought about by a continuous starting and stopping, as in a step-by-step method, which is employed in order to obtain the various points the loci of which determine the *B–H* curves. This viewpoint has an analogy in the well-known difference between starting and running friction.

If these assumptions be true, to bring a demagnetized material to a given induction might require more energy if magnetized from a state of rest than would be required to bring the material from zero flux to the same induction if a change of flux is already taking place in that direction, as would be the case if the magnetism started from some flux density of negative or opposite polarity.

Referring again to Fig. 1, curve "*A*" is the typical form when started at zero induction, the specimen having been demagnetized, whereas, if the specimen should have a polarity in the opposite direction of such a value that the flux would have a zero value when *H* is also zero and the process continued without stopping, the resultant conditions in the specimen might be as represented by curve "*B*."[1] The energy of static inertia or the additional energy to start and accelerate the movement or to change the direction and velocity of movement or the energy representing the difference between running and starting friction may be determined by the area between the two curves "*A*" and "*B*."

SUGGESTED TESTS.

Methods of attack would include:

1. The taking of a number of *B–H* curves starting at zero flux and zero field, having previously demagnetized the specimen.
2. The taking of a number of *B–H* curves starting at a negative value of flux density and a negative field, selecting such values as would cause the curve to pass through zero flux and zero field simultaneously and then to continue the observations.

[1] In order to obtain a hysteresis loop where zero flux occurs simultaneously with zero "*H*" it is necessary to select conditions where one of the maximum flux values is greater than the maximum flux value at the opposite polarity. Such a loop is unsymmetrical. See "The Unsymmetrical Hysteresis Loop," John D. Ball, *Trans. A. I. E. E.*, Vol. XXXIV, Part 2, 1915, pp. 2275–2297.

3. The taking of a number of B–H curves wherein each point is taken by a single step from zero flux and field to the point in question and also to reach the same value of H by several steps, observing the flux changes and comparing the sum of the flux changes with the flux change when arriving at the same H value in a single step. If additional energy is required to start the motion producing flux change, at each step, then the sum of the flux changes to arrive at a definite H value will be less as the number of steps is increased.
4. The taking of a number of hysteresis loops proceeding step by step, using as few steps as possible to determine properly the graph, and repeating the tests taking an increasing number of points. Comparison of the loops might show an increased area with an increased number of points.
5. The analyses of such curves as may be obtained with a view of determining any empirical equations which might satisfy the curves.

There are some practical difficulties and limitations involved in the above outline of suggestions which may be mentioned here:

1. First and foremost we must consider just what consists of the right conditions in a magnetic specimen which will give us zero flux and zero field or proper demagnetization. Demagnetization is a study in itself and magnetic curves are governed not only by the specimen being apparently demagnetized but also by previous magnetic history with special reference to how demagnetization was accomplished.[2]

2. The measurements are of small quantities and include not only properties of materials but differences between apparent properties of materials under various conditions. This means that small measurements are involved which require delicate instruments and, as the differences are small percentages of the measured properties, accurate methods and technique are demanded.

3. The magnetic creepage is most noticeable at low densities and may be a considerable factor. It is to be remembered

[2] "The Best Method of Demagnetizing Iron in Magnetic Testing," C. W. Burrows, *Bulletin of U. S. Bureau of Standards*, Vol. 4, No. 2, pp. 205–274.

that the ballistic galvanometer measures only the flux change occurring within one quarter of the time of its natural period. Consequently it must be determined what creepages are involved and if flux changes occur after the quarter period of the galvanometer they must be measured.

4. The damping of the galvanometer itself must be determined. If a number of steps are taken to reach a definite value of H and compared with the flux value of reaching the same H in a single step, we must be sure that the several dampings of the galvanometer do not appreciably affect the observations.

5. Step-by-step methods in themselves are not as accurate as where curves are determined by obtaining each point directly from a maximum flux density or a reference point. All continuous step methods are susceptible to this cumulative error.

6. There is a fundamental difficulty due to the fact that we are interested in values of B and H when passing through points without stopping, and stopping is necessary to determine the points by the usual ballistic galvanometer methods.

7. In determining the path of the B–H curve where energy may be required to start and bring about the magnetization a difficulty arises in making the proper interpretation of the results obtained, as it is quite possible that this energy may be stored in the magnetic material and discharged after the field strength, or corresponding current, has reached its value at the end of each step. This discharging of energy may be absorbed by raising the flux to a higher value than is immediately reached when the current arrives at the point in question. This is a form of magnetic creepage and may occur in time to be registered by the galvanometer or may continue to occur after its "swing" or quarter period. Even if this be true to a certain extent we still have the consideration of the difference between starting and running friction, which energy is not recovered, as it is dissipated in heat.

MATERIALS TESTED.

For the purpose of the present tests two rings were selected, one of which was of standard iron and the other silicon steel.

The principal measurements are:

Outer diameter 8.9 cm.
Inner diameter 6.87 cm.
Mean length of magnetic circuit 24.77 cm.
Thickness of sheets 0.036 cm.

Windings:

1. Potential, or galvanometer, coil, 200 turns No. 20 double cotton covered wire, dia. = 0.081 cm.
2. Magnetizing coil, 100 turns No. 16 double cotton covered wire, dia. = 0.13 cm.

Sample *A*:

Standard iron. Annealed. Sp. gr. (assumed) 7.7.[3]
Wt. = 421.74 grams.

Sample *B*:

Silicon steel. Approximately 3.5 per cent. silicon. Annealed.
Sp. gr. (assumed) 7.5.[3]
Wt. = 422.75 grams.

The apparatus and methods used during the tests are so generally known as to require no description here.

DEMAGNETIZATION.

A considerable number of tests were made to determine exact data as to the *B–H* curves which would be obtained when various methods of demagnetizing were used.

The method which is doubtless the most reliable and is used as the standard of comparison is that recommended by the U. S. Bureau of Standards. The method is described in the Bureau's *Bulletin*.[4]

> "The demagnetization should be accomplished by a current reversed at the rate of approximately one cycle per second, while gradually diminished in such a way that the rate of decrease of the induction is as nearly as may be uniform, ... The initial demagnetizing current should be sufficient to carry the induction beyond the knee [5] of the *B–H* curve, and the final current should be

[3] In accordance with specifications of the American Society for Testing Materials.

[4] *Ibid.*, page 274.

[5] It is unfortunate that the Bureau refers to the "knee" of the *B–H* curve. This apparent bend, often called the "knee" of the curve, is not a magnetic

not greater than the smallest magnetizing current to be used."

In the subsequent discussion we will refer to this method as Method "*A*."

In the *Bulletin* already referred to, attention is called to the fact that zero flux and zero field may be obtained by various methods, but the method used will affect the nature of the *B–H* curve taken after the various methods of demagnetization.

In investigating the possibilities of inertia or friction differences governing the shape of *B–H* curves, demagnetizing by other methods which gave the same zero flux-zero field or "state point" was performed.

MAGNETIC ELASTICITY.

If a material is magnetized and the field be removed, the magnetism will fall to a flux value indicated on the loop as the residual magnetism or the point where the curve crosses the axis of zero field. However, if a negative value of current equal to the coercive force were applied either by steps or by a single throw, the flux value would be brought to zero but upon removing the current the flux will increase toward the same direction or polarity whence it came. The flux apparently "springs back" to a certain extent toward the value of the residual magnetism. As this characteristic has not been named, the designation "magnetic elasticity" strongly suggests itself.

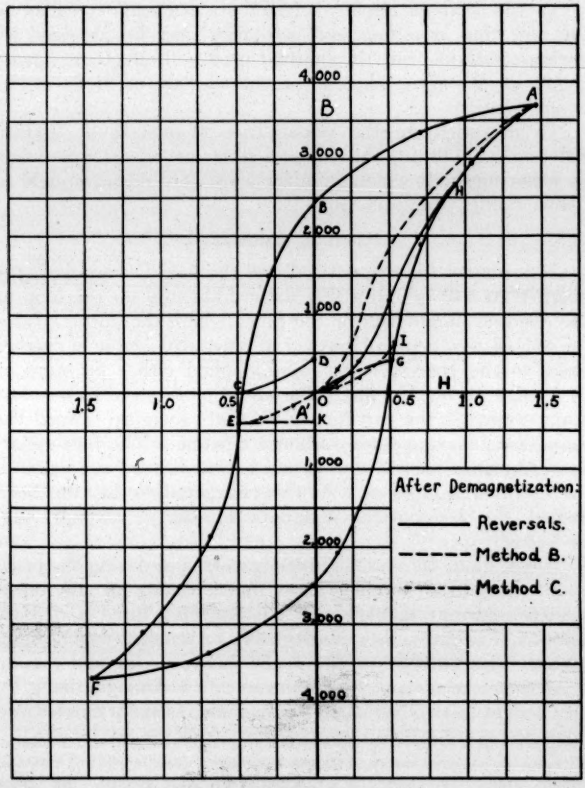
Tests, made by various investigators and during the process of the present inquiry, show that by using an amount of negative current in excess of the coercive force a definite amount of negative flux density may be reached which, upon release of the current, results in the flux reversing and coming to an exact zero value the same as when demagnetizing by the slow reversals,[6] but when the specimen is again magnetized

property but is an artificial condition which apparently occurs at any number of different values of flux density which can be brought about by plotting curves to different scales. The "knee" is a function of the scale selected. See "Some Notes on Magnetization Curves," John D. Ball, *Gen. Elect. Review*, Vol. XVIII, Jan., 1915, pp. 31–35.

[6] This is shown by Messrs. Smith and Hammond in "Neutral Magnetization in Iron," *The Physical Review*, Vol. XV, April, 1920, pp. 249–255.

we find very different results, which depend upon the method by which the zero flux value was obtained. For convenience

FIG. 2.



B–H curves after various methods of demagnetization.

of reference we will call the method of demagnetizing by the application of the negative current Method "*B*."

A third method of obtaining zero flux is to obtain a flux density and then reverse the flux to the same density of the opposite polarity. Then by applying a proper amount of positive current greater than that of the coercive force, the removal of this current results in the flux springing back to zero. If now the material be magnetized in the positive direction, a still different *B–H* curve results from that obtained by the above described process. This last method is the same in effect as Method "*B*" except the further magnetization is performed at the opposite polarity. We will call this Method "*C*."

These methods may be shown by reference to Fig. 2. The hysteresis loop is the path *A–B–C–E–F–G–I–H–A*. *O–B* is the residual magnetism and *O–C* the coercive force. If the material is demagnetized by current reversals, the "state point" of zero flux and zero field or current is reached at point *O*. If now the *B–H* curve be determined, it will follow a path such as represented by *O–H–A*.

If from point *A* the curve *A–B–C* be determined, upon removing the current the path of the curve is from *C* to *D*. Demagnetizing by Method "*B*" consists of continuing the curve *A–B–C* to *E*. Upon removing the current the flux path will be *E–O*. Now if the *B–H* curve be determined it will follow path *O–A*. Demagnetizing by Method "*C*" consists of curve *A–B–C–E–F–G* and releasing current continuing curve from *G* to *O*. If now the *B–H* curve be determined, we will obtain curve *O–I*.[7]

A THEORY OF MAGNETIC ELASTICITY.

Theoretical considerations indicate magnetic elasticity is to be expected if our theory regarding the first bend in the *B–H* curve is correct.

This also satisfies the conditions that when demagnetizing by alternating current we obtain consistent amounts of residual magnetism. Also such a situation is consistent with the observed facts that the plotted data do not always give us a closed loop.

[7] There are, of course, other methods of demagnetization, such as diminishing amounts of applied alternating current. See G. F. C. Searle, *Proc. of Inst. of Elect. Engrs.*, Part 170, 1904, pp. 55–118, and "Demagnetization of Iron," A. W. Smith, *Physical Rev.*, Vol. X, Sept., 1917, pp. 284–290.

It is suggested that, when the material is originally magnetized, energy is stored in the material before movement takes place, as in any elastic body subjected to a mechanical pull. This storing of energy may be due to static inertia, elasticity or, perhaps, to some other simple cause. When the current is removed this energy is released and is dissipated in changing the flux density. Energy absorbed due to friction will, of course, be dissipated in the form of heat.

It is quite likely that the energies may be measured by areas and that relationships exist, for example, between the areas, between curves *A* and *B* of Fig. 1, which represents the energy absorbed in magnetization which does not produce an additional flux change, and area *O–K–E–O*, Fig. 2, which represents the energy released by the breaking of the current, which energy produces a flux change.

TESTS. SERIES I.

A number of tests were made to determine point *E*, Fig. 2. This point represents a negative current value the release of which permits the flux value to return to zero.

The proof of zero flux consisted of the simple test of reapplying the current to give the maximum flux density desired and then reversing the direction of the current and, in both instances, noting the flux change. When repeated trials showed the flux change on reversal to be twice that obtained on applying the current, we know that the original flux value was zero.

After the point *E* was obtained, *B–H* curves were determined for test specimens of silicon steel and standard iron to various values of *B* maximum.

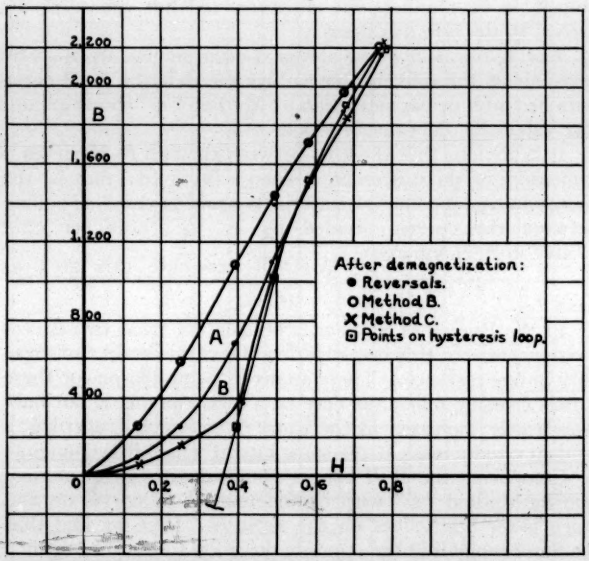
Tests were made after each of the three methods of demagnetization and in each case hysteresis loops were obtained for each maximum value of *H* and for each method of demagnetization.

The *B–H* tests were made by the well-known Roland ring method and the hysteresis loops by the step-by-step method. In every case the observations were repeated a number of times with the same increments of *H* and the final data taken as the average flux increment for each change of *H*. The maximum variation in any one test from the mean value taken was slight in every instance.

DISCUSSION OF TEST RESULTS.

Fig. 3 is typical, showing the nature of the *B–H* curves following the three methods of demagnetization previously described. These emphasize, as has already been pointed out, that great care must be taken properly to demagnetize magnetic material and in interpreting results. These curves again prove that the obtaining of a zero flux value in itself is

FIG. 3.



B–H curves of silicon steel to *B* max. 2,200. Area *A* = 14.2 ergs. Area *B* = 7.8 ergs.

not sufficient, as the material possesses different potentialities depending upon its previous magnetic history.

The reason that the three *B–H* curves are not alike is a matter of great interest and possible importance. It is evident that although at zero flux values the magnetic elements are in a state where the plus magnetisms and negative magnetisms neutralize each other, yet obviously this is

accomplished in a different manner for the three cases considered.

It is of especial interest to note that, when the flux density is already being changed in a certain direction (as regards positive and negative) or when the material is in a state of rest after having been changed in a certain direction, further flux changes in the same direction are accomplished, to a certain flux density at least, with less energy than if the flux change is in the opposite direction to that preceding its arrival to the zero flux density.

Taking the *B–H* curve obtained after demagnetization by reversals as the reference curve, we see that the *B–H* curve obtained after demagnetization by Method "*B*" shows greater flux values for the same *H* values.

It is obvious that the area between the two *B–H* curves is a measure of the difference of energy involved; that is, the energy in ergs per cm.^{3} of material is equal to the *B–H* square between the curves, divided by 4π, i.e., ergs per cm.^{3} $= \frac{\text{area in } B\text{–}H \text{ squares}}{4\pi}$. We will designate this area as Area "*A*."

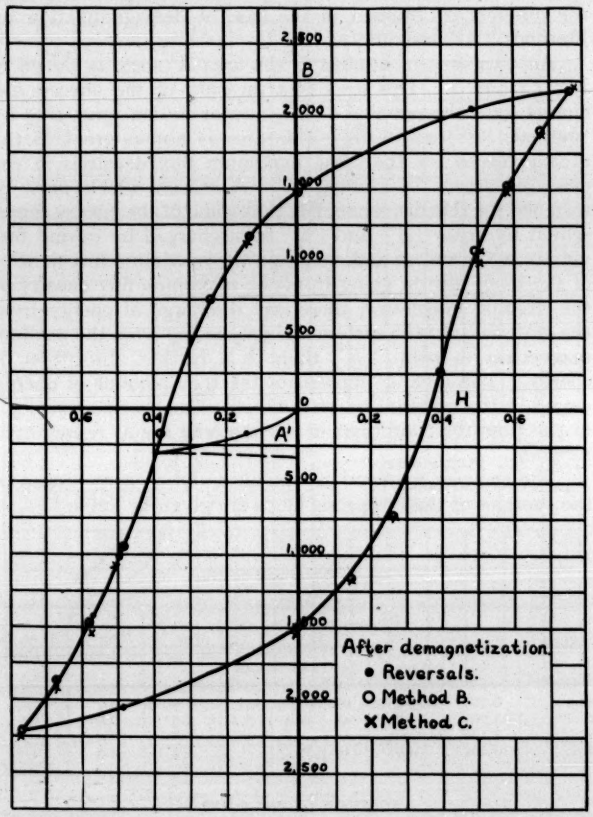
In the Bureau of Standards publication these two curves cross whereas in this investigation the curves meet but cross only in one instance. There seems to be no reason for these curves crossing unless, as may be a fact, the flux is not only more easily increased in the same direction, but also has a tendency to increase at the same rate at which it is changing.

Comparing the *B–H* curves obtained after demagnetization by Method "*C*" with the reference *B–H* curve, we find much lower flux values for the same *H*. Here we find that the flux change is in the opposite direction from that in which demagnetization was accomplished and consequently greater energy is required to obtain a given flux density, the additional amount of which may be found from the area between these two *B–H* curves, which we will designate as Area "*B*."

From the tests made, this third *B–H* curve seems the least easy to explain. It approaches the ascending quarter of the hysteresis loop very rapidly and in some cases goes beyond the loop, that is, for a given *H* the *B* value is less than the points on the loop. The points on this *B–H* curve in some instances

also recross the loop and again show points inside the loop as the induction is raised.

FIG. 4.



Hysteresis loops of silicon steel. B max. = 2,184. Loss = 203 ergs. Area $A' \simeq 3.5$ ergs.

Fig. 4 is a typical hysteresis loop which shows that if three loops were drawn to represent the points obtained after

the three methods of demagnetization there would not be a great difference in areas. The results obtained after demagnetization by Method "*C*" show greater differences than the differences obtained in the case of demagnetization by Methods "*A*" and "*B*."

Another area of interest is the area *A'* such as shown in Figs. 2 and 4. This area is a measure of the energy discharge after the removal of the current in demagnetizing by Methods "*B*" and "*C*." This area is not as great as the area involved for the same maximum flux densities in the cases of areas "*A*" and "*B*." A reason which may be assigned for this discrepancy is that some of the energy represented by areas "*A*" and "*B*" is discharged by raising flux values at the end of each step and the maximum flux density of the loop; also in going from the maximum flux density to the residual magnetism there is a discharge of energy from the material into the system and proceeding from the residual magnetism to point "*E*" there is a further absorption of energy. The area *A'* represents the true amount of energy stored in the material by virtue of the "magnetic elasticity" at the time the conditions in the material are as represented by point "*E*".

The energies involved as amounts and as percentages of the energies of the hysteresis loops are given in Table I.

TABLE I.

Energies Represented by Areas.

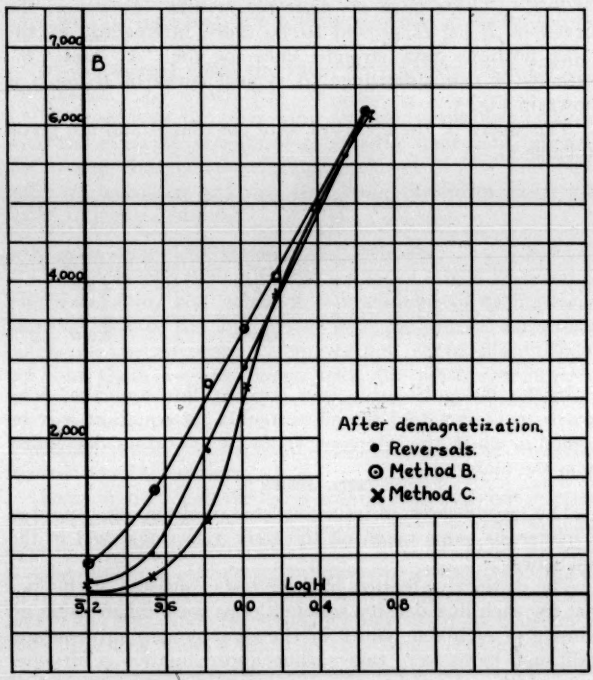
Steel.	*B* max.	Losses in Ergs.				*A* as % of Loop.	*B* as % of Loop.	*A'* as % of Loop.
		Loop.	*A*	*B*	*A'*			
si.....	6,190	1,143	87	65	13	7.6	5.7	1.1
si.....	3,702	482	41	14.5	5.3	8.5	3.0	1.1
si.....	2,184	203	14	4.8	3.5	6.9	2.4	1.7
std.....	6,264	1,695	110	39		6.5	2.3	

EQUATION OF B-H CURVES.

In 1891 Dr. A. E. Kennelly showed that for magnetic materials the reluctivity (which is the reciprocal of the permeability), when plotted against the magnetizing force *H*,

gives a curve which from minimum reluctivity upwards approximates a straight line over a wide range of values.[8]

FIG. 5.



B–log *H* curves of silicon steel to *B* max. 6,260.

Equations for these curves have been published in previous papers.[9]

[8] "Magnetic Reluctance," A. E. Kennelly, *Trans. A. I. E. E.*, Vol. VIII, 1891, pp. 485–517.

[9] "Reluctivity of Silicon Steel," John D. Ball, *Gen. Elect. Review*, Vol. XVI, 1913, pp. 750–754.

"Investigation of Magnetic Laws for Steel and Other Materials," John D. Ball, JOUR. FRANKLIN INST., Vol. 181, 1916, pp. 459–504.

In the present investigation attempts were made to find if the results gave any rational equation. Curves were plotted showing the relationships between B–H, log B–log H, and log B–H. These gave no desirable results. However, the curves of B–log H proved to be more interesting, as the upper portions gave straight lines for the "A" and "B" methods of demagnetizing. A typical curve of B–log H is shown in Fig. 5.

The slopes of these curves were calculated and are given in Table II.

TABLE II.

Slopes of B–log H Curves.

Steel.	B max.	Slopes demag. A.	Slopes demag. B.
si.....	6,190	5,220	4,130
si.....	3,702	5,570	4,280
si.....	2,184	5,570	3,880
std.....	6,264	13,950	8,870

If the B–log H curve is a straight line and the slope proves to be constant for all materials, an equation may be formed in which the intercept would be a constant depending upon the material.

TESTS. SERIES II.

The second series of tests consisted of obtaining a number of hysteresis loops taken on the same two rings used in the first series.

The distinctive feature of these tests consisted of the fact that for each flux density selected loops were taken using an average of eighteen points in the step-by-step process and additional loops were taken using approximately a fifty per cent. additional number of points.

The object of the two groups of tests at the same inductions was to find if there were any differences in the losses indicated or if, at a given induction, more energy would be required as the number of steps involved became greater. On the theory of static inertia being a governing factor in determining the energy required to effect a flux change, or if the difference in losses due to starting and running friction, or similar phenomena, are appreciable, loops involving a greater number

of points or more stops and starts might show a greater area, which would indicate that there was more energy required.

The same method of testing was used as in the first series except that the precision of the galvanometer readings was improved by the substitution of microscopic lenses for the eye piece.

In the second series the rings were always demagnetized by Method "*A*," which is by reversals.

In every case the tests were repeated a number of times with the same increments of H and the final data taken as the average flux increment for each change of H. The maximum variation, in any one test, from the mean value was slight in every instance.

DISCUSSION OF TEST RESULTS.

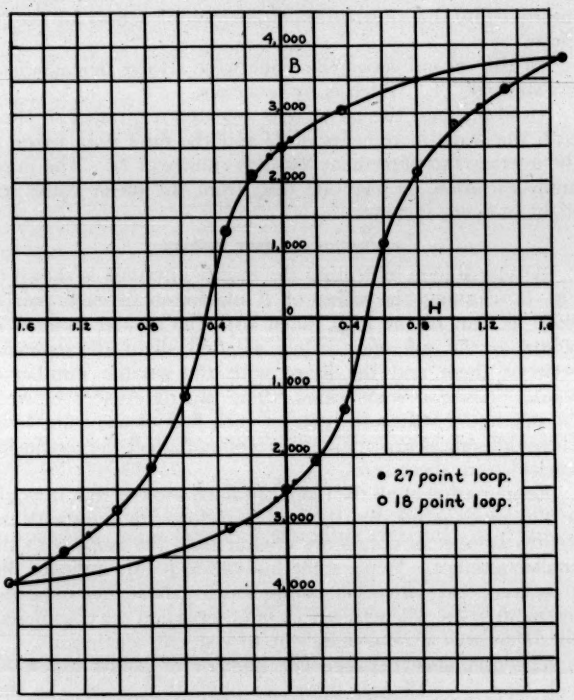
A typical loop indicating the results obtained is shown on Fig. 6. Taking the value of B maximum of each pair of loops as that of the loop taken with the greater number of points as the reference value, we find slight discrepancies between them and the loops with the smaller number of points. Also, in some cases, there are differences between the maximum values in cases of each half of the same loop. These differences are small and would not affect the conclusion reached from these tests.

Examination of all the loops obtained showed that it would be difficult to prove that the hysteresis losses of loops with the greater number of points are greater than the loops with the smaller number. While some individual points indicate this to be true, there are other points which indicate the opposite, and in all cases, when the errors of observation are considered, the differences are not sufficient to warrant conclusions.

The difference between the number of points taken for each loop is small and there are obvious reasons why this part of the investigation cannot be extended to any great extent. If fewer points were taken, it would be difficult properly to determine the true shape of the loop; in fact the areas would depend somewhat upon the shape of the curve rule in the possession of the investigator. Additional points involve cumulative errors and these affect results, depending not only on their direction and amount but also on the part of the curve where the points in question occur.

A more fruitful analysis proved to be the comparing of the maximum flux densities which were reached with a given

FIG. 6.



Hysteresis loops of silicon steel. *B* max. = 3,824. Loss = 526 ergs.

maximum *H* value in cases where the loop was taken point by point and in cases where the *H* values were reversed or where a half loop is taken in a single step. This comparison is shown in Table III, which includes test results from both Series I and Series II.

TABLE III.

Comparison of Maximum Points.

SERIES I.

Steel.	Avg. Density Hyst.	Avg. Density Reversals.	Hyst. Density Dif. from Reversals.
si.....	6,190	6,260	− 70
si.....	3,702	3,763	− 61
si.....	2,184	2,200	− 16
std.....	6,264	6,290	− 26

SERIES II.

si.....	1,368	1,378	− 10
si.....	2,540	2,568	− 28
si.....	3,806	3,838	− 32
si.....	5,173	5,188	− 15
std.....	1,471	1,479	− 08
std.....	2,623	2,645	− 22
std.....	9,054	9,000	+ 54

In all but one case the B maximum obtained by reversals exceeded those obtained by reaching them by the steps of the loops.

Tests were made to determine the amount of errors, if any, which might be due to "magnetic creepage." These tests showed that no such errors are involved in the present investigation.

A series of tests were made which showed that the self-damping of the galvanometer need not be considered as affecting the results obtained.

ACKNOWLEDGMENTS.

The investigation, of which this paper is an abstract of the results obtained, was conducted in the Physics Department of Marquette University at Milwaukee, Wisconsin, and was submitted to that institution as partial requirements for the Degree of Doctor of Philosophy. The work was done under the direction of Dr. Charles H. Skinner, whose guidance, interest and encouragement were more than inspirational.

The results obtained were made available through the tests performed by Mr. Simon Share, a student in the College

of Liberal Arts at Marquette University. His untiring efforts and patience cannot be acknowledged too highly.

The furnishing of the test specimens was one of the many courtesies received by the author from Mr. James R. Craighead, late of the General Electric Company.

SUMMARY.

In this investigation the first series of tests consisted of obtaining zero flux in two varieties of steel from various maximum flux values and by three different methods. *B–H* curves were obtained after demagnetization by the three methods and from the maximum value of these *B–H* curves hysteresis loops were taken.

One method of demagnetizing was that suggested by the U. S. Bureau of Standards, which consists of current reversals through a magnetizing winding, in which current values are gradually reduced to zero. The second method consisted of applying a negative current of such an amount that the resultant value of flux would be such that when the current was released the flux value would go to zero. The third method was substantially the same as the second except the zero flux was approached from the direction of opposite polarity.

The resultant *B–H* curves proved to be different from each other and to depend upon not only their origin but the previous history of the material as regards methods of demagnetization.

The areas between the curves were evaluated.

It was found that in cases of two of the three typical *B–H* curves the *B*–log *H* curves gave straight lines for part of the range involved.

A second series of tests consisted of taking a set of hysteresis loops and repeating the determinations, using a greater number of steps to find if by taking a greater number of steps there might be a greater indicated energy loss. The results of this group of tests were not sufficiently definite to warrant conclusions.

MILWAUKEE, WISCONSIN,
May 14, 1928.

ARMATURE REACTION IN MULTIPOLAR DIRECT CURRENT DYNAMOS.

BY

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IT is generally understood that armature reaction affects the flux entering the armature and plays an important part in determining the operating characteristics of dynamos. It is therefore a subject of considerable interest to those engaged in the design or operation of electrical machinery.

Any conductor carrying electric current sets up a magnetomotive force in every path linking the conductor. The conductors on the armature of a dynamo are therefore sources of magnetomotive force (m.m.f.) whenever current flows in them. Under no-load conditions, the field windings are the only sources of m.m.f. in the magnetic circuits of a dynamo, but it is apparent that when the machine is loaded the armature also produces an m.m.f. The magnetic flux entering the armature from the field poles, is therefore due to the combined m.m.f.s of the field windings and of the armature windings. The magnetic effect of the armature is generally known as armature m.m.f. or armature reaction.

Various explanations, usually of a rather qualitative and superficial nature, applying to the special case of a two-pole dynamo, are to be found in numerous sources, but a simple quantitative explanation based wholly on fundamental principles is not common. It is the purpose of this article to derive from the fundamental principles involved, a reasonable explanation of armature reaction equally applicable to multipolar and bipolar machines.

The greatest difficulty in obtaining a clear understanding of problems in which magnetic circuits are involved, is probably due to an almost universal misconception of the nature of the common unit of m.m.f. the "ampere turn." This name is in itself somewhat misleading and it might well be called "ampere conductor" instead, as we shall see later.

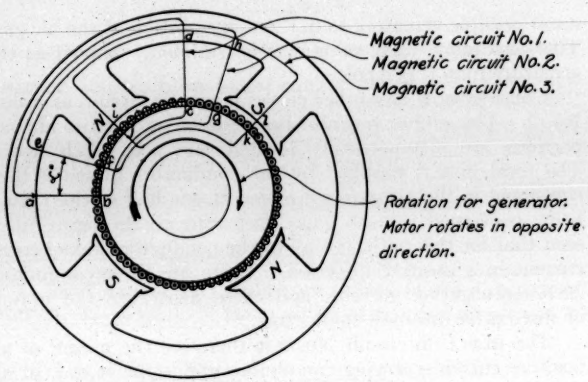
There is, probably due to this name, the common though incorrect conception that an ampere turn is a complete loop of wire carrying one ampere, inferring that the return conductor must be coiled and in close proximity to the outgoing wire. It is this last inference that is wrong, for the location or form of the return conductor does not change the magnitude of the m.m.f. that the electric circuit supplies to any magnetic circuit linking it. *A conductor carrying a current of one ampere exerts a m.m.f. of one ampere turn on any and every closed path linking it, regardless of whether the return wire be near or far from it.* For example, a transmission line wire carrying one ampere exerts a m.m.f. of one ampere turn on any path surrounding it. Suppose, that an iron rod were bent in the form of a ring about the wire. The flux induced in this iron ring by the straight transmission line wire would be the same as if a small turn of wire carrying one ampere were wrapped closely about the ring. Furthermore, the path chosen about the transmission line wire need not be of iron. It may be a path in the air normally surrounding the conductor. Regardless of the material or the shape of the path, and regardless of whether the return conductor hugs the outside surface of the path or returns miles distant, *if a conductor carrying one ampere links a magnetic circuit it exerts in this circuit a magnetomotive force of one ampere turn.* If N conductors link the magnetic path, each carrying I amperes, the m.m.f. on the path (and on every other path linking the conductors) is N times I ampere-turns or $0.4\pi NI$ gilberts.

Whenever current flows in the armature conductors of a dynamo, these conductors are therefore sources of m.m.f. in all magnetic paths linking the conductors. The flux in the magnetic circuits of the machine is therefore the result of the combined magnetomotive forces of field and armature windings.

The effect of the current in the armature conductors can best be shown by considering a particular case, and applying to it the fundamental principles above outlined. Figure 1 shows a four-pole dynamo with brushes set on the no-load neutral, i.e., in such a manner that current in the armature conductors reverses midway between each pair of poles. On the armature, from the center line midway between one pair

of poles to the center line between the next pair, there is therefore a group of conductors in all of which current flows in the same direction, and in which the value of the current is I_c, the armature current per path.

FIG. 1.



Armature reaction with brushes set at geometric neutral.

Excepting for high saturation in the iron portions of the magnetic circuit, the yoke and pole may be considered as one magnetic equipotential surface. It is not necessary to make this assumption, but in order to keep this explanation as simple as possible, it will be made in this discussion.

Consider now, the closed magnetic circuit No. 1, in Fig. 1. This is so drawn that the air portions of the path, a–b, and c–d, are exactly one pole pitch apart, and hence are symmetrically located. All conductors enclosed in this path carry current in a + direction. The total armature m.m.f. in the closed circuit a, b, c, d, due to the conductors linked with it, is therefore NI_c, where N is the number of conductors per pole pitch and I_c the current per conductor. Since, on the assumption of zero reluctance of the iron circuit, the two air paths a–b, and c–d, consume all this m.m.f. and since they are symmetrically chosen, the m.m.f. on a–b equals m.m.f. on path c–d $= \frac{NI_c}{2}$.

Circuit No. 1 has purposely been chosen at the geometric neutral. It is seen that in this circuit, all the armature conductors linking it, carry positive current and that therefore, the armature m.m.f. that acts on path a–b of this circuit is equal to $\frac{\text{conductors per pole pitch} \times I_c}{2}$, which is the maximum possible armature m.m.f. on any portion of the air gap. This maximum value of m.m.f. is commonly known as the armature m.m.f. per pole.

Consider now any other closed magnetic circuit, as circuit No. 2. This circuit has also been chosen so that its air gap portions are symmetrically located one pole pitch apart. The total m.m.f. supplied by the conductors linked is then consumed in the air gaps e–f and g–h, one half of the m.m.f. being consumed in each gap. Referring to the figure, it is seen that for this path, not all of the conductors linked carry current in a positive direction. There are three conductors carrying negative current, and these neutralize the m.m.f. of three other positive conductors.

The m.m.f. in circuit No. 2 is therefore the m.m.f. of all positive current-carrying conductors minus the m.m.f. of all negative current-carrying conductors enclosed in the path. In this case, since there are 16 conductors enclosed, three of which carry negative current, the net ampere turns in circuit No. 2 is $13I_c - 3I_c = 10I_c$. The m.m.f. on path e–f is therefore half this value or $5I_c$ ampere turns.

This argument can readily be generalized, and put into mathematical form, where

N = conductors per pole,
I_c = current per conductor,
α = displacement in electrical degrees of path No. 2 from the geometric neutral.

Since there are 180 electrical degrees per pole pitch, the number of conductors carrying negative current is

$$\frac{\alpha}{180} N.$$

The net effective conductors carrying positive current are then

$$N - \frac{2\alpha}{180} N$$

and the net effective ampere turns in the closed circuit are

$$I_c\left(N - \frac{2\alpha}{180} N\right).$$

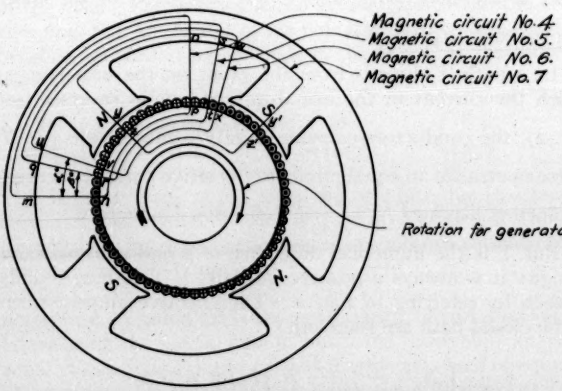
The ampere turns on the path e–f is one-half of this value, or, armature ampere turns at e–f equals $\frac{NI_c}{2}\left(1 - \frac{2\alpha}{180}\right)$ .....(1).

It is to be noted that the armature m.m.f. as given above is a linear function of α. It has a maximum value of $\frac{NI_c}{2}$ at geometric neutral, and zero value where $\alpha = 90°$, i.e., directly upon the center of the pole.

EFFECT OF SHIFTING BRUSHES.

If, as in Fig. 2, the brushes are shifted in the direction of rotation, by an angle β, the position of reversal of current in

FIG. 2.



Armature reaction with brushes shifted $\beta°$ off geometric neutral.

the armature conductors shifts forward with the brushes. The maximum armature m.m.f. will now be exerted in the

path linking conductors, all of which carry + current, i.e., the circuit including the two air paths immediately above the brushes. The m.m.f. in this path is exactly the same as the m.m.f. at the geometric neutral path before the brushes were shifted. It may be noted further that the armature m.m.f. in any path is now exactly the same as for a similar path in Fig. 1, situated β degrees farther back.

This effect may also be expressed mathematically. In the following discussion, let

α = angular displacement of the magnetic path under consideration, from geometric neutral,
β = angular brush shift ahead (in direction of rotation), from geometric neutral,
I_c = current per conductor,
N = number of conductors per pole,
$Y = (\beta - \alpha)$.

The maximum armature m.m.f. occurs where α equals β, at which point all conductors linking the circuit carry current of the same sign. The m.m.f. of the whole circuit at this point is therefore NI_c, or, for one side (g–h) of the path, ampere turns equal $\frac{NI_c}{2}$.

In a path Y degrees from the point on the armature at which the current in the armature conductors reverses (see Fig. 2), the conductors carrying negative current are $\frac{Y}{180}N$. These neutralize an equal number of positive current-carrying conductors leaving $\left(N - \frac{2Y}{180}N\right)$ effective conductors.

But Y is the numerical difference of β and α irrespective of sign; it is always a positive quantity. This may readily be seen by referring to Fig. 2. The effective ampere turns in the closed path are therefore

$$\left(N - \frac{2(\alpha - \beta)}{180}N\right)I_c \text{ for } \alpha > \beta$$

or

$$\left(N - \frac{2(\beta - \alpha)}{180}N\right)I_c \text{ for } \beta > \alpha.$$

The armature m.m.f. per air gap (path g–h, Fig. 2) is therefore

$$\frac{NI_c}{2}\left(1 - \frac{2(\alpha - \beta)}{180}\right) \text{for } \alpha > \beta \ldots\ldots\ldots (2)$$

and

$$\frac{NI_c}{2}\left(1 - \frac{2(\beta - \alpha)}{180}\right) \text{for } \beta > \alpha. \ldots\ldots\ldots (2a)$$

The ampere turns at the geometric neutral are now those given by the above equation where α equals 0, or

$$\frac{NI_c}{2}\left[1 - \frac{2\beta}{180}\right]\ldots\ (3)$$

This quantity is in general known as the cross magnetizing component of armature ampere turns. It is the total m.m.f. tending to produce flux at the geometric neutral position of the machine, since the net pole m.m.f. at this point is zero.

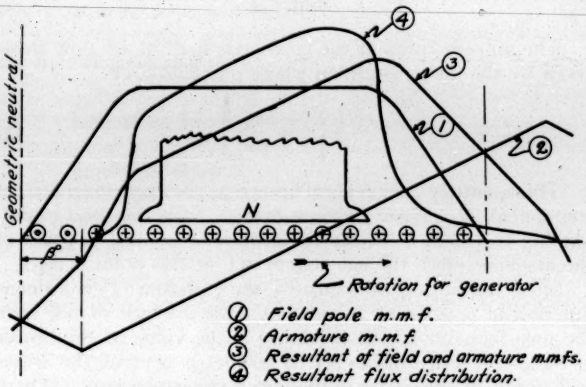
Since the m.m.f. as shown by the equation (2) is a linear function of α (β being a constant), the average m.m.f. over the pole face due to the armature is the value at the center of the pole. For brushes set on geometric neutral, the armature m.m.f. at the center of the pole is seen to be zero. Where brushes are shifted by an angle β, the m.m.f. at the center of the pole is

$$\frac{NI_c}{2}\left[1 - \frac{2(90 - \beta)}{180}\right] = \frac{NI_c}{2}\left(\frac{2\beta}{180}\right) = NI_c\left(\frac{\beta}{180}\right)\ldots\ldots (4)$$

This is the average m.m.f. over the pole face due to armature current. Since with brushes shifted in the normal direction (forward in a generator or backward in a motor), this part of the armature m.m.f. is opposed to the field m.m.f. It is commonly known as the demagnetizing component. It may be noted that equation (2) is the general form of equation (1), the latter being the special case in which the brush shift angle β is zero. Equations (3) and (4) are also special cases of equation (2), equation (3) being the case when the displacement angle, α, from geometric neutral is zero, and equation (4) the case when α is 90 degrees.

The armature m.m.f. for a particular case such as represented in Fig. 2 may now be plotted for each point on the armature surface. This results in a triangular form such as shown in curve No. 2, Fig. 3, with maxima above the points on the armature where current reverses.

FIG. 3.



Magnetomotive force and flux curves with brushes shifted β° off geometric neutral.

The total m.m.f. effective to send flux into the armature is now the resultant m.m.f. of the windings on the pole, and the armature. The m.m.f. of the pole can readily be calculated, its maximum value being the product of the turns per pole and the field current. It is practically constant under the pole face, and decreases rapidly in almost linear form from the edges of the pole to the geometric neutral, as shown in curve 1, Fig. 3. The m.m.f. of the pole is less than its maximum value on some of the flux paths beyond the pole tips, because the flux that enters the armature at these points, does not link all of the field windings. That is, the flux emerges from the pole at some point above the lower edge of the field coil. The resultant of curves 1 and 2 is the m.m.f. setting up flux in the magnetic circuit (curve No. 3).

The flux density at any point on the armature may now readily be calculated if the average reluctance of the path

from the pole and yoke structure to the armature be known. For this calculation, consider a flux path terminating on one sq. cm. of the armature surface. In the air gap under the pole, the path of flux is easily and accurately estimated. In the interpolar space, the determination of this flux distribution is not so simple, but a fair approximation may be made by cut and try methods. Details of such methods may be found in various books on generator design. Having determined the flux distribution, it is then a fairly simple matter to calculate the reluctance of a flux tube ending on one sq. cm. of the armature surface. The density at this point on the armature is then equal to the m.m.f. as shown on curve 3, divided by the reluctance of the flux tube. In this manner a resultant flux distribution curve as shown by curve No. 4, Fig. 3, may be drawn.

This curve is of particular importance since it shows the final effect of the armature m.m.f. in distorting the flux distribution, and consequently indicates the distortion of the generated voltage in the coils of the machine.

A Calorimeter for the Determination of the Heat Developed by Fruit. EZER GRIFFITHS. (*Proc., Phys. Soc.*, London, Feb. 15, 1928.) To the plant physiologist a knowledge of the rate of production of heat by apples is of value for the light it throws on the oxidation of sugar and malic acid and the formation of carbon dioxide, while to the refrigerating engineer it furnishes data of use in caring for cargoes of apples.

The measurements were conducted in a small room maintained at a constant temperature. In this was a metallic box well insulated with granulated cork. Two identical containers were within the box; one held apples, the other dummy apples of spheres of thin glass filled with wet glass wool to provide the same heat capacity as the real apples in the first receptacle possessed. Into each container projected four tubes each of which held 10 yards of nickel wire. This wire formed a resistance thermometer, the 40 yards in each enclosure being joined in series. The total wire in each container was joined to an arm of a slide wire bridge so arranged that a shifting of the contact by one cm. along the wire indicated a difference of temperature between the enclosures of .003° C. A current of air flowed for long periods through the aggregate of apples. By regulating its speed it was possible to keep them in atmospheres containing from 2 to 10 per cent. of CO_2. Since water was evaporated by the air current, its gain in humidity had to be determined and the heat of vaporization allowed for.

The rise in temperature observed was of the order of magnitude of .15° C. Unsound apples developed about 50 per cent. more heat than sound ones. The content of CO_2 in the atmosphere surrounding the apples scarcely affected the heat development at all. The energy removed by the air current represented from ⅓ to 4 per cent. of the total heat developed by the fruit.

"From the preliminary observations recorded in this paper, it may be assumed that a cubic foot container of apples at a temperature of 20° C. generates heat at the rate of 0.14 calorie per second." On this basis 100,000 bushel cases of apples would evolve heat at the rate of 132 H.P. The heat conducted inward through the sides of the vessel is about three times as great as that produced by the apples.

G. F. S.

MEDAL DAY MEETING.

THE annual Medal Day meeting of The Franklin Institute was held in the Hall of the Institute on the 16th of May. It was also the stated monthly meeting for May, and was called to order by the acting president, the senior vice-president, Mr. Henry Howson.

The acting president announced that the minutes of the last meeting had been printed in the May number of the JOURNAL and that, if there were no objection, the minutes would be approved as printed. As no objection was offered, the minutes were declared approved.

The acting president called upon the secretary, Dr. Howard McClenahan, who announced the donation to the Institute of a portrait of Mr. William Sellers, a former president and long time member of the Board of Managers of The Franklin Institute. The portrait had been especially painted for the Institute and was presented by the son of Mr. Sellers, Alexander Sellers, Esq., of Philadelphia. The Secretary made expression of the sincere appreciation of the Institute for this greatly valued portrait.

The Chairman of the meeting then announced that the presentation of medals was the next order of business, and stated that all of the medals which had been awarded during the present Institute year, upon the recommendation of the Committee on Science and the Arts, would be presented at this time.

AWARD OF LONGSTRETH MEDALS.

To Dr. Frank N. Speller, National Tube Company.

The Chair recognized Mr. G. H. Clamer, sponsor for Dr. Speller. Mr. Clamer said: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Frank N. Speller of the National Tube Company, as the recipient of the Edward Longstreth Medal, in consideration of his invention of a method of manufacturing scale-free pipe and its successful application."

The Chairman presented the medal, certificate and report in the following terms: "Dr. Speller, by virtue of the authority conferred upon me by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon recommendation of the Committee on Science and the Arts, and with the unanimous approval of the Board of Managers of the Institute, an Edward Longstreth Medal. I congratulate you upon this deserved recognition."

In acknowledging the award, Dr. Speller said: "I wish to express my thanks for the honor you have done us and assure you it is much appreciated."

To Mr. Warren P. Valentine, Philadelphia, Pa.

The Chair recognized Dr. G. S. Crampton, sponsor for Mr. Valentine, who said: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Warren P. Valentine, as the recipient of an Edward Longstreth Medal, in consideration of the meritorious work shown in the improvement of the mechanical and optical part of the Abbe Refractometer, thereby increasing its accuracy."

In making the presentation of the medal and certificate the acting president said: "Mr. Valentine, I have much pleasure in presenting to you, in the name of The Franklin Institute of the State of Pennsylvania, upon recommendation of its Committee on Science and the Arts, and with the unanimous approval of its Board of Managers, the Longstreth Medal and Certificate. I congratulate you upon the masterly workmanship upon which this award is based."

In acknowledgement of the award Mr. Valentine said: "Mr. Chairman and Members of the Board, I wish to express my appreciation and thanks for this award."

AWARD OF WETHERILL MEDALS.

To Mr. Albert S. Howell, The Bell-Howell Company.

The Chair recognized Mr. W. N. Jennings as sponsor for Mr. Howell.

Mr. Jennings: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Albert

S. Howell, of the Bell-Howell Company, as the recipient of the John Price Wetherill Medal, in consideration of the ingenuity shown in successfully embodying the principles of the professional moving picture camera and projector in instruments especially adapted to the use of the amateur and for the excellence of construction of these instruments."

The Chairman spoke as follows: "Mr. Howell, I am very glad to present to you, on behalf of The Franklin Institute and upon the recommendation of its Committee on Science and the Arts, and with the hearty approval of its Board of Managers, the John Price Wetherill Medal and Certificate. We are gratified to have you added to the honor roll of The Franklin Institute."

Mr. Howell said, "Thank you."

To Dr. Frank E. Ross, Yerkes Observatory, University of Chicago.

The Chair recognized Prof. W. R. Wright as sponsor for Dr. Ross.

Professor Wright: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Frank E. Ross, of the Yerkes Observatory, in absentia, as the recipient of a John Price Wetherill Medal, in consideration of his marked contributions to Astronomy in the design of wide angle astrographic lenses of exceptional speed and definition."

The Chairman then presented the medal and certificate to the Secretary of the Institute: "Mr. Secretary, by authority vested in me, I confer upon Dr. Frank E. Ross, by action of the Board of Managers, a John Price Wetherill Medal and Certificate. I request that you transmit them to Dr. Ross with our congratulations."

The medal and certificates were received by the Secretary for transmission to Dr. Ross.

AWARD OF LEVY MEDAL.

To Professor Vannevar Bush, Massachusetts Institute of Technology.

The Chair recognized Professor H. J. Creighton, sponsor for Professor Bush.

Professor Creighton: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Professor Vannevar Bush of the Massachusetts Institute of Technology, as the recipient of the Louis Edward Levy Medal, with special reference to his fellow workers, Messrs. G. F. Gage, H. L. Hazen, H. R. Stewart, for two papers, 'A Continuous Integraph' and 'Integraph Solution of Differential Equations' which appear in the JOURNAL OF THE FRANKLIN INSTITUTE for the year 1927."

The Chairman presented the award in the following terms: "Professor Bush, I have much pleasure in conferring upon you the Louis Edward Levy Medal and Certificate, with congratulations to you for the high quality of the articles upon which this award is based, and with special mention of your three co-workers, Messrs. Gage, Hazen and Stewart."

Professor Bush replied: "I am highly appreciative of the honor which is conferred upon me by The Franklin Institute, and I am sure I can also convey to you the appreciation of my fellow-workers."

AWARD OF HENDERSON MEDAL.

To Mr. William F. Kiesel, Jr., the Pennsylvania Railroad.

The Chair recognized Mr. G. H. Benzon, Jr., sponsor for Mr. Kiesel.

Mr. Benzon: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. William F. Kiesel, Jr., of the Pennsylvania Railroad, as the recipient of the George R. Henderson Medal, in consideration of his numerous inventions of outstanding value in locomotive and railway car design and construction."

The Chairman in presenting the medal and certificate said: "Mr. Kiesel, The Franklin Institute is happy to confer upon you, upon the recommendation of its Committee on Science and the Arts, the George R. Henderson Medal and Certificate, and to congratulate you upon your many and valuable contributions to Railway Engineering and Equipment."

Mr. Kiesel responded: "I appreciate the honor conferred upon me by you on behalf of The Franklin Institute."

AWARD OF CLARK MEDAL.

To Arthur Graham Glasgow, Esq., Humphreys and Glasgow, Ltd., London, England.

The Chair recognized Mr. F. R. Wadleigh, sponsor for Mr. Glasgow.

Mr. Wadleigh: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Arthur Graham Glasgow, of London, England, as the recipient of the Walton Clark Medal, in consideration of his outstanding and valuable work in the technology and development of the manufactured gas industry."

In presenting the Medal and Certificate the Chairman said: "Mr. Glasgow, by virtue of authority vested in me, I confer upon you, in the name of The Franklin Institute of the State of Pennsylvania, the Walton Clark Medal and Certificate. I congratulate you upon your many contributions of value to the gas industry, and at the same time wish to express our appreciation to you for your trip from London, England, to receive this medal."

Mr. Glasgow in accepting the award, said: "It is to me intensely gratifying to receive the Walton Clark Medal, as the second recipient of it from this ancient and eminent institution. I thank you."

AWARD OF POTTS MEDALS.

To Dr. Eugene E. Sullivan, in absentia, and Mr. William E. Taylor, of the Corning Glass Works.

The Chair recognized Mr. C. A. Hall, sponsor for Messrs. Sullivan and Taylor.

Mr. Hall: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Eugene C. Sullivan and Mr. William E. Taylor, of the Corning Glass Works, as joint recipients of a Howard N. Potts Medal, in consideration of the noteworthy contribution to the art of glass manufacture resulting in what is known as pyrex, a glass that has desirable qualities both for domestic and scientific purposes."

The Chairman presented the medal and certificate to Mr. Taylor: "Mr. Taylor, I have the honor to confer upon Dr.

Sullivan, in absentia, and you, jointly, the Howard N. Potts Medal and Certificate. I ask you to convey our congratulations to Dr. Sullivan upon his return from Europe, at the same time that you receive a full measure for yourself."

Mr. Taylor said: "I greatly appreciate this honor which you have conferred upon Dr. Sullivan and upon me, and I desire to thank you."

To Mr. Oscar G. Thurlow, the Alabama Power Company.

The Chair recognized Mr. F. H. Rogers, sponsor for Mr. Thurlow.

Mr. Rogers: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Oscar G. Thurlow of the Alabama Power Company, as the recipient of the Howard N. Potts Medal, in consideration of the novelty and ingenuity of its design, the careful investigation of the various elements affecting such design, its usefulness in increasing the potential output of hydroelectric plants under certain conditions and the successful application of his Backwater Suppressor."

The Chairman presented the medal and certificate to Mr. Thurlow and said: "Mr. Thurlow, we are happy to confer upon you the Howard N. Potts Medal and Certificate and to express our admiration for the ingenuity and sound knowledge embodied in your invention."

In expressing his appreciation Mr. Thurlow said: "I deeply appreciate this honor and not only for myself, but for my co-workers."

AWARD OF CRESSON MEDALS.

To Professor Vladimir Karapetoff, Cornell University.

The Chair recognized Mr. C. W. Bates, sponsor for Professor Karapetoff.

Mr. Bates: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Professor Vladimir Karapetoff, as the recipient of the Elliott Cresson Medal, in consideration of the ingenuity, inventive ability, skill in design and detailed theoretical knowledge of kinematics and

electrical engineering displayed in the development of his kinematic computing devices."

The Chairman presented the medal and certificate as follows: "Professor Karapetoff, by virtue of the authority conferred upon me by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon the recommendation of the Committee on Science and the Arts and with the unanimous approval of the Board of Managers of the Institute, the Elliott Cresson Medal and Certificate. As a student of physical science, I am grateful to you for your successful efforts to lighten the burden of electrical calculations."

Professor Karapetoff replied: "I deeply appreciate the honor and I take this opportunity to thank those who financed the project and made it possible."

To Mr. G. W. Elmen, Bell Telephone Laboratories, Inc.

The Chair recognized Mr. C. A. Hall, sponsor for Mr. Elmen.

Mr. Hall: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Gustaf W. Elmen of the Bell Telephone Laboratories, Inc., as the recipient of the Elliott Cresson Medal, in consideration of his extended researches in the magnetic characteristics of nickel-iron alloys resulting in the invention of permalloy, an alloy having high permeability and low hysteresis loss, and of its successful uses for the loading of submarine telegraph cables to secure high speed transmission, for the cores of loading coils and audio frequency transformers."

The Chairman presented the medal and certificate to Mr. Elmen in the following terms: "Mr. Elmen, The Franklin Institute is delighted to confer upon you the Elliott Cresson Medal and Certificate and to add you to our honor list because of your important discovery of permalloy."

Mr. Elmen responded: "I wish to express my deep appreciation of the honor conferred upon me."

To Mr. C. L. Lawrance, Wright Aeronautical Corporation.

The Chair recognized Mr. W. L. Brown, 3d, sponsor for Mr. Lawrance.

Mr. Brown: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Charles L. Lawrance of the Wright Aeronautical Corporation, as the recipient of the Elliott Cresson Medal, in consideration of his pioneer work in the development of the air cooled airplane engine, of his skill in bringing this engine to a high degree of perfection, and of his ability in carrying out its manufacture."

The Chairman then presented the medal and certificate: "Mr. Lawrance, I have great pleasure in conferring upon you the Elliott Cresson Medal and Certificate, and to congratulate you heartily upon the epochal development of the air cooled airplane engine for which you are responsible."

Mr. Lawrance said: "I want to thank you and the members of the Institute for this honor, and I want to thank you also on behalf of my co-workers in the Wright Aeronautical Corporation, who greatly helped to make the engine what it is today."

To Mr. Henry Ford, Ford Motor Company.

The Chair recognized Mr. Benjamin Franklin, sponsor for Mr. Ford.

Mr. Franklin: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Henry Ford of Detroit, Michigan, as the recipient of the Elliott Cresson Medal, in consideration of his rare inventive ability and power of organization by means of which he was able to effect high speed production of automobiles, revolutionizing the industry; and his outstanding executive powers and industrial leadership."

The presentation of the medal and certificate was made by the Chairman as follows: "Mr. Ford, in the name of The Franklin Institute, I am delighted to present to you the Elliott Cresson Medal and Certificate for your revolutionary contributions to the automobile industry. Few men have had the privilege of altering radically and happily the life of the world which you have known. We congratulate you sincerely."

In acknowledging the award, Mr. Ford said: "I am highly honored and thank you very sincerely."

AWARD OF FRANKLIN MEDALS.

To Professor Doctor Walther Nernst, University of Berlin.

The Chair recognized Dr. James Barnes, sponsor for the Franklin Medalists of the day.

Dr. Barnes: "Mr. Chairman, the Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts was unanimously of the opinion that a Franklin Medal be awarded to Doctor Walther Nernst, Professor of Physical Chemistry in the University of Berlin and Director of Technical Physics at the Reichsanstalt 'in recognition of his numerous and valuable contributions in physical and theoretical chemistry and particularly for his applications of the exact methods of thermodynamics to electro- and thermo-chemistry.'

"Doctor Nernst was born in 1864. After studying and teaching at Würzburg, Leipzig and Göttingen he was appointed in 1905 to the most distinguished chair of physical chemistry in the German Republic, that at the University of Berlin. In 1920 he received the Nobel Prize and in 1921 he was Rector of the University of Berlin.

"Professor Nernst is without a peer in the field of physical chemistry. Even to list his fundamentally important researches and discoveries would be a long task. I cannot however refrain from referring to his investigations and measurements of the specific heats of solids at extremely low temperatures, the results of which led to that important principle known as the Nernst Heat Theorem—the most valuable contribution to thermodynamics since the days of Clausius, Maxwell and Helmholtz.

"Mr. Chairman, it is a source of keen regret to all that Doctor Nernst is unable to be here today. We are, however, highly appreciative of the courtesy of His Excellency Baron von Prittwitz-Gaffron, the German Ambassador to the United States, in coming to us from Washington to receive on behalf of Doctor Nernst this medal and certificate. I have, Sir, the honor and pleasure of presenting to you Baron von Prittwitz-Gaffron."

The Medal, Certificate, and Certificate of Honorary Membership were then presented to the German Ambassador by the Acting President, in the following manner:

"Dr. Nernst cannot be with us in person today because of the marriage of his daughter in Berlin at this time. He is, however, admirably and delightfully represented by the Ambassador from Germany to the United States, Dr. von Prittwitz-Gaffron, who has kindly come from Washington to attend our Medal Day exercises and to receive The Franklin Medal and Certificate and Certificate of Honorary Membership in the Institute on behalf of Dr. Nernst. Your Excellency, I have much pleasure in presenting these symbols of honorable consideration to you, with the request that you transmit them to Dr. Nernst with our compliments."

He then said: "Ladies and Gentlemen, the Ambassador from Germany to the United States."

The Ambassador, in accepting the medal on behalf of Dr. Nernst, spoke as follows: "It is indeed a great honor for me to be present at the Medal Meeting of the distinguished Franklin Institute and to receive, on behalf of Professor Walther Nernst of the University of Berlin, the valuable distinction which has just been bestowed upon him. I beg to express on his behalf to the President and the Board of Managers of The Franklin Institute his highest appreciation and sincere gratitude for the Franklin Medal, as well as for the honorary membership of the Institute which has been conferred upon him.

"Professor Nernst has asked me to convey to you his deepest regrets that he has not been able to come to the United States to be present here today and to receive in person the distinction awarded to him. Professor Nernst hopes, however, that he may have the opportunity some time in the future to come over from Germany in order to offer to you personally his sincerest thanks.

"As representative of the German Republic I may be permitted to express how deeply honored not only German science but the German Nation as a whole is, by the fact that Professor Nernst is the second German scholar who has been presented with the high distinction of the leading Medal in Physics in the United States and the honorary membership of The Franklin Institute.

"Your distinguished Institution has thereby once more shown its conception of the universality of science, a concep-

tion which Goethe expressed in the true and simple words: 'Science and art belong to the world, before them the barriers of nationality disappear.' This spirit of scientific cooperation between the nations is very highly appreciated and understood in Germany, which stands for an international scientific community. We hope and trust that the spirit of an ever closer understanding and cooperation may be spread throughout the world in the mutual interest of progress for the benefit of humanity and the advancement of civilisation. In this work Philadelphia occupies a conspicuous place, which ever has been an international scientific center and where, long ago, the collaboration in the field of scientific research with the other nations was initiated by that great American, whose name your institution bears, Benjamin Franklin."

The Chairman: "Mr. Ambassador, on behalf of The Franklin Institute I thank you heartily for your marked kindness in coming to us today. Your presence adds much to this occasion."

To Dr. Charles F. Brush, Cleveland, Ohio.

Dr. James Barnes presented Dr. Brush for the Franklin Medal with the following statement: "Again, Mr. Chairman, the Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts was unanimously of the opinion that a Franklin Medal be awarded to Doctor Charles F. Brush, Electrical Engineer, of Cleveland, Ohio, 'in recognition of his invention and development of the first successful arc light system for illumination and of the first practical storage battery.'

"Doctor Brush was born in Euclid, Ohio, in 1849. He was educated at the University of Michigan, receiving the degree of M.E. in 1869. In 1899 he received the Rumford Medal from the American Academy of Arts and Sciences and in 1913 the Edison Medal from the American Institute of Electrical Engineers. Doctor Brush was the pioneer in the scientific development of arc lights and of the necessary electrical apparatus in connection therewith. The same can be said of his work in connection with the storage battery. Both of these epoch-making developments are essential today in our daily pursuit of work for most of us and of pleasure for

a few of us. He is truly a great inventor and a great benefactor. Although almost four score years of age, Doctor Brush is still 'going strong' intellectually and physically. He cannot stop investigating and, like our daring aviators, he is plunging into unknown scientific regions—a field bristling with difficulties. You will hear about this in his paper this afternoon. America is proud of Doctor Brush and The Franklin Institute is happy to number one of its oldest and most faithful members as a Franklin Medalist. I therefore, have much pleasure, Mr. Chairman, in presenting to you Doctor Charles F. Brush."

The Chairman presented the Medal, Certificate and Certificate of Honorary Membership to Dr. Brush as follows: "Dr. Brush, it is particularly gratifying to us of The Franklin Institute to present to you a Franklin Medal and Certificate and a Certificate of Honorary Membership in the Institute in consideration of your epoch-marking inventions and your life of devotion to scientific advancement. We bespeak for you many years of continued health and honor among your fellowmen."

In acknowledgment, Dr. Brush said, "I thank you and The Franklin Institute."

After the presentation of the medals, the acting president made the following announcement: "In the absence of Dr. Nernst, Dr. Irving Langmuir of the General Electric Company, Schenectady, N. Y., a former student under Professor Nernst in Europe, one of the great contributors to the modern theory of atomic structure, has kindly come from Schenectady to Philadelphia in order to present today the paper, 'Physico-Chemical Considerations in Astrophysics' which has been prepared for this meeting by Dr. Nernst. I have much pleasure in presenting Dr. Langmuir." (The paper prepared by Dr. Nernst which was read by Dr. Langmuir appears on page 135 in this number of the JOURNAL of the Institute.)

In appreciation of his cooperation the Chairman said: "Dr. Langmuir, I thank you heartily in the name of the Institute for your kindness in coming here today."

The Chairman then announced: "We shall now have the second paper of the day, prepared by our newest Franklin Medalist, Dr. Charles F. Brush of Cleveland, Ohio, one of

America's greatest inventors." (The paper read by Dr. Brush appears on page 143 of this issue of the JOURNAL.)

The Chairman dismissed the meeting with the following statement: "Ladies and Gentlemen, we have been glad to have you with us at our Medal Day exercises and are appreciative of the interest and consideration which have caused your presence here. The meeting is now adjourned."

HALL OF THE INSTITUTE,
May 16, 1928.

Evidence for the Gravitational Displacement of Lines in the Solar Spectrum Predicted by Einstein's Theory. C. E. St. John. (*Astrophys. J.*, April, 1928.) By Einstein's theory wave-lengths of radiation starting in the sun's atmosphere should be somewhat longer than the wave-lengths of the same radiation originating on the earth. This displacement toward the red end of the spectrum is directly in proportion to the wave-length but in no case is it more than minute. For a wave-length of 3800 angstrom units it amounts to only .008 unit and for 6600 A it is .014 A.

In this paper comparison is made between the wave-lengths of 1537 spectral lines at the center of the sun's disc and 133 at its edge and the wave-lengths of the same lines in a vacuum source on the earth. It is of powerful evidential value that in not a single case was a terrestrial line discovered to have a longer wave-length. In a few instances no difference was found and in the others the difference was in the direction predicted by Einstein's theory. Most of the lines measured were due to iron but confirmatory results were obtained with 6 lines of silicon, 18 of manganese, 402 of titanium and 515 of cyanogen. For iron lines coming from the center of the sun's disc and originating 520 km. above the photosphere the mean displacement toward the red is .009 A., while the theoretical Einstein displacement is .0091 A. For lines from higher levels the shift is greater than the theoretical value and from lower levels it is smaller. To upward currents in the sun's atmosphere such differences are largely attributable. The observational work was done at the Mount Wilson Observatory. G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

FUTURE INTERNATIONAL BASIS FOR ELECTRICAL UNITS.

By amendment to the International Convention on Weights and Measures it has been provided that electrical units and standards shall be dealt with through the organizations which have jurisdiction over the fundamental units of Measurement. These organizations are the international General Conference, the International Committee, and the International Bureau of Weights and Measures. (See *The Technical News Bulletin*, No. 127, November, 1927.)

The seventh General Conference on Weights and Measures, held in 1927, approved the formation of a committee on electricity to advise the permanent International Committee on Weights and Measures on questions relating to electrical standards and systems of measurement. This advisory committee was limited to ten members, including a representative appointed by each of the national laboratories designated by the International Committee and additional Specialists named individually by that Committee. It was provided that a member of the International Committee should be chairman of the advisory committee and that a report should be rendered by it not later than March 1, 1929.

The national laboratories designated are the National Physical Laboratory of Great Britain, the Laboratoire Central d'Electricité at Paris, the Physikalisch-Technische Reichsanstalt of Germany, the Central chamber of Weights and Measures of the Union of Socialist Soviet Republics (Russia), the Electrotechnical Laboratory of the Department of Communications of Japan, and the National Bureau of Standards of the United States. Of the four additional members only two appointments have been announced. These are M. Chas. Guillaume, Director of the International Bureau of Weights and Measures, and Professor L. Lombardi of Rome, Italy. An American advisory committee has been formed to assist

* Communicated by the Director.

the Bureau of Standards in formulating proposals representing a consensus of the opinions held in this country. The organizations invited to take part and the representatives named as members of this committee are as follows:

National Academy of Sciences—Professor A. E. Kennelly.
American Institute of Electrical Engineers—Professor A. E. Kennelly.
American Physical Society—Professor Henry Crew.
National Electric Light Association—Dr. Clayton H. Sharp (Alternate—Mr. A. B. Morgan).
Association of Edison Illuminating Companies—Dr. Clayton H. Sharp.
National Electrical Manufacturers Association—Mr. W. J. Canada.
American Telephone and Telegraph Company—Mr. A. B. Clark.

The questions which these committees have before them may be considered as threefold, namely (1) the relative functions of the International Bureau and the several national laboratories in the future maintenance of the electrical units, (2) The particular values of the units to be adopted, (3) the methods to be used to assure the constancy of these units. These questions are, however, closely interrelated, and in particular the answers to the first two depend upon the last one.

The American Advisory Committee met at the Bureau of Standards on June 16, 1928, together with a number of members of the staff of the Bureau. After due consideration of the information available regarding the present status of electrical measurements, the Committee unanimously adopted the following resolutions:

1. *Resolved*, that in the opinion of this Committee, in view of improvements which are being made in absolute measurements, electrical standards should in future be based upon the absolute system of units.

2. *Resolved*, that in the opinion of this Committee, the functions which it is desirable to have the International Bureau of Weights and Measures undertake in connection with the electrical units, are as follows:

"(1) A central secretariat to arrange for systematic

exchange of Standards and compilation of results of intercomparisons thus made among the national laboratories.

"(2) A laboratory to which concrete standards representing the results obtained in the different countries may be brought for precise comparisons.

"(3) A repository for international reference and working standards with the necessary equipment so that other standards may be compared with these standards on request."

Resolutions of similar purport have been under consideration by committees of the American Institute of Electrical Engineers for some months, and were finally approved by the Board of Directors during the Denver Meeting, June 25–29, 1928. The official text of these resolutions has not been published, but it is understood that it is in print as follows:

WHEREAS, there is conclusive evidence that there are discrepancies between the statutorily established international electrical units (ohm, ampere, and volt) and the fundamental ohm, ampere and volt, which the international units were intended to represent, these discrepancies in the case of the ohm and the volt amounting to approximately one-twentieth of one per cent.; and

WHEREAS, differences of this magnitude are objectionably large in comparison with the precision required and now being attained in the construction and use of standards fundamental to all electrical measurements; therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake, as soon as possible, the additional researches necessary in order that legislation to reduce these discrepancies to within acceptable limits may be enacted in the near future.

And WHEREAS, the present electrical units are defined by statute in terms of material standards, namely, the mercury ohm and the silver voltmeter, which it is now known only approximately represent the absolute ohm and ampere and which experience has shown to have serious limitations, and

WHEREAS, such progress has been made in recent years in the art of making absolute electrical measurements in terms

of the fundamental units of length, mass, time, and space permeability that the accuracy and reproducibility of a system of electrical units realized by such absolute measurements would seem to be adequate for commercial, industrial and scientific purposes; and

WHEREAS, the legalization of the absolute ohm and ampere and the units derived from them (these units to be realized by the national standardizing laboratories) would avert the recurring proposals for revision of the values of the legalized units, and would establish the electrical units on a permanent legal basis: therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake as soon as possible, the additional researches necessary in order that the absolute ohm and absolute ampere based on the absolute volt, watt and other units derived from them, may be legalized in place of the international ohm and ampere and their derived units.

Resolved, further, that in order to avoid the confusion which would result from an interim use of new empirical units based on corrected values of the international units, the international electrical units should be continued in effect without any readjustment of values until such time as the practicability of legalizing the above-mentioned absolute units shall have been determined.

Even after national standardizing laboratories were established these arbitrary primary standards were considered the most practical basis for defining the units and for checking from time to time the values maintained by resistance coils and standard cells. Developments during the last twenty years have, however changed the situation materially. In the first place, the standards used purely for maintenance purposes have proved surprisingly dependable: in the second place, all scientific workers have come to depend upon the great national laboratories to supply certified standards, so that no other laboratory expects to set up independent reference standards; and finally, the experience gained in electrical measurements together with the refinements made in electrical theory have apparently made it possible to determine absolute

values for the ohm and ampere with an accuracy not less than that attained in reproducing the international units by the prescribed arbitrary primary standards.

The excellent performance of the modern wire resistance coil and standard cell makes it possible to maintain the units for many years with a certainty greater than the values can be reproduced by any single method. In actual practice whenever mercury ohm determinations have been made during the last twenty years, the results have been considered as agreeing with the wire standards within the limits of accuracy attainable by the mercury tubes, and *the values assigned to the wire standards have not been changed.* Similarly, the second unit actually maintained throughout that period has been the volt, represented by the standard cell: in fact no final agreement has ever been reached on the precise specifications for the silver voltmeter to represent the second international unit.

The logical conclusion seems to be to recognize the fact that the nominally accepted international system of reproducing the units has not worked in actual practice, but that out of experience there has developed a better system. This consists of highly dependable maintenance standards which will serve to maintain continuity and uniformity of values, these values being subject to change by international agreement only when the accumulated evidence of repeated determinations by all available experimental methods shows that there has been a drift or that the values assigned to the working standards are not exactly what they should be.

Looking forward to the need for the most accurate possible values of the electric units in the absolute system, the Bureau of Standards inaugurated some years ago a program of research in this field. This program is now being pushed forward more rapidly, and, although as a whole it must extend over many years, it is hoped that some preliminary results will be at hand before the report of the International Advisory Committee is due in March, 1929. In the meantime, the opinions of American technical societies, as recorded in the resolution quoted above, are being put before the International Advisory Committee. Representing as they do the unanimous action of the organization concerned, these recom-

mendations should have great weight, and the position of this country in these international relationships is correspondingly strengthened by this complete understanding and hearty coöperation between governmental agencies and the scientific, industrial and commercial organizations intrusted in the problem.

RADIO FADING IN THE BROADCAST RANGE.

FOR the past several months an investigation has been conducted by the Bureau of Standards to determine the factors contributing to the phenomenon known as fading. Special apparatus utilized in conjunction with radio receiving sets makes it possible to secure graphic records of the increase and decrease of signal strength such as are commonly experienced when listening to programs from distant stations at night. This apparatus, sufficiently sensitive to indicate variations smaller than the ear can detect, was used with receiving systems employing different types of antennas to analyze the manner in which the waves transmitted from a broadcasting antenna arrive at the receiving antenna.

The factors which may cause variations in the intensity of radio waves are complex, and a critical study of fading has suggested explanations of some of these factors.

Graphic records of a single selected transmission were made using identical receiving sets except for the antennas. The antenna systems used in the course of the investigation were (1) vertical antenna, (2) coil antenna directed toward the station being received, (3) coil antenna with planes at right angles to the direction of the transmission path, (4) combination of coil antenna and vertical antenna connected in such a way as to eliminate waves received directly from the station. Simultaneous records were made using two receiving sets with different types of antennas.

Examination of data from simultaneous measurements made with a soil antenna in maximum position and with a vertical antenna, respectively, indicated that for stations 165 to 1500 kilometers distant the same sort of fading occurred simultaneously in both antennas, but that for stations 13 to 53 kilometers distant similar fading characteristics did not occur simultaneously.

Records made with coil antennas at maximum and minimum positions showed that for a station 300 km. distant, for instance, there are considerable periods in which an increase of intensity in one antenna is accompanied by a decrease in the other. Often a relatively rapid and periodic fluctuation of small magnitude is found superposed on the longer period trend of the records. It was found that, for one station at least, this superposed, rapid fading of periodic type occurs with considerable regularity directly after sunset and lasts for approximately a half hour.

The results may be interpreted to mean that the waves do not reach the receiving antenna in the same position relative to antenna in which they start, i.e., their plane of polarization is changed. This change only takes place when the wave has been reflected. Several reflections from different points may take place, resulting in there being at the receiving station two or more waves which started at the same time from the transmitting station and traveled very different paths before reaching the receiving station.

More detail concerning these phenomena will be given in a paper to be published at a later date. Notice of this publication will be given in the *Technical News Bulletin.*

FIRE EXPOSURE CONDITIONS IN MASONRY-WALLED BUILDINGS HAVING COMBUSTIBLE INTERIOR CONSTRUCTION.

BUILDINGS of this class constitute a majority of the business structures in our towns and cities. The masonry walls afford protection to the building in case of fire in neighboring buildings, particularly with protected wall openings, and again they decrease the hazard to the surroundings when the given building burns, although freedom from collapse of enclosing walls not supported on adjacent construction cannot be promised after the interior floor construction has fallen.

The severity of fires in buildings of this type is of interest mainly as it concerns exposure to the surrounding buildings, to party and fire walls, and to protected containers located within the building, such as insulated safes and vaults. Previous tests made at the Bureau of Standards to obtain

information on the severity of building fires have simulated conditions in buildings having fire resistive interior as well as exterior construction that will withstand a complete burning-out of combustible contents and trim without collapse of major structural members, such as walls, floors, columns, and roof. Items relative to these tests have been given previously in this bulletin and the first technical paper giving the results with office and record storage occupancies has been published (Proceedings 14th Annual Meeting of the Building Officials' Conference, 1928; and *Quarterly* of the National Fire Protection Association, Vol. 22, No. 1; July, 1928). This interprets the results of burning-out tests in rooms having fire resistive enclosures and combustible contents from 13.1 to 55.4 lbs./ft.^{2} of floor area (105,000 to 440,000 B.t.u. per square foot) assumed uniformly distributed, in terms of hours of equivalent fire exposure in the standard furnace test used to rate the fire resistance of building materials, constructions, and devices.

In case of fires in buildings with combustible interior construction there is an initial period of fire exposure before floor and roof construction collapses the severity of which is measurable by the same means and in the same terms as that of fires in fire resistive buildings. Beyond the point of collapse of floors, roof, column, and wall constructions, the air temperatures, except immediately above the debris, go down to points presenting little hazard. The temperature in the debris continues, however, at higher points for long periods and is of interest as it concerns exposure to safes, vaults, and party and fire walls, that may be covered, partly covered, or in the contact with it. Temperatures measured in the debris from heavy furniture and high loaded shelves in the tests previously referred to indicated a more severe condition than that of the fire exposure above it, although the piles were not as high as would be expected from the collapse of several floors of a non-fire-resistive building. In building fires it is recognized that the most severe exposure for insulated safes and vaults is the prolonged heating in the ruins where water is not applied.

The lack of information on what is the severity of exposure under such fire conditions, led to requests that the bureau

include tests with such buildings in its work on intensity and duration of building fires. This matter was of particular interest to the Committee on Protection of Records of the National Fire Protection Association, as a basis for assigning suitable degrees of protection for records in buildings of given heights and combustible contents. The opportunity for conducting a test of this kind presented itself in connection with the Government building program in Washington that involved the razing of buildings on several squares. Two adjoining buildings, previously housing mercantile occupancies, one two stories 20 feet wide, the other five stories and 30 feet wide, both 75 feet long, were placed at the bureau's disposal through the courtesy of the Treasury Department. These buildings had brick walls and open wood-joisted floor and roof construction, the floors being of one inch boards on 3-inch-thick joists. Both buildings had open stair and elevator shafts, very few partitions, and generally presented conditions favorable for rapid spread of fire.

The buildings were loaded with waste lumber to give superimposed load of combustibles of $7\frac{1}{2}$, 15, and 30 pounds per square foot of floor area for the front, middle and rear 25-foot sections, respectively, of all floors of the two buildings. Thirty-two insulated safes were located on the various floors, mostly along the walls. Most of them were donated by manufacturers and represented degrees of fire resistance from less than one hour to fully four hours of fire resistance as exposed in the standard furnace test. Five old safes were also included, three of which were supplied by the Post Office Department. Each safe was loaded with paper and in each was also placed maximum indicating thermometers. In all safes above the ground floor was also placed an alarm clock fitted with a trigger that would stop the clock movement when the position of the safe was disturbed, this being intended to indicate the time the safes dropped because of collapse of the supporting floor. About 50 thermocouples were inserted through the outside walls a few feet above the different floors and a similar number extended from hollow posts erected and anchored into the concrete floor slab near the ground level of both buildings. These thermocouples connected with an instrument room 100 feet to the rear of the buildings. The

rest of the buildings in the square as well as in the adjoining square on one side had been razed at the time of the test, the nearest building being approximately 200 feet away. To decrease the hazard to the surroundings, the side walls of the higher building were trussed together with rods above the roof line to delay the collapse of the walls, and new sheet steel roofing was placed over the old roofing to aid in holding down the volume of flame, hot gases, and brands that might escape during the height of the fire. At a conference held immediately before the test with safe manufacturers and others interested it was decided to continue this test to the point of cooling down of ruins without the application of water.

Fires were started at several points on the ground floor of both buildings at nearly the same time early on the morning of June 17, the time being chosen to avoid interference with the usual activities of the district in which the buildings were located. The day was clear with little or no wind. The fire spread rapidly up through the open stair and elevator shafts and within ten minutes nearly all portions of the two buildings were involved. In the course of 15 to 20 minutes the wooden floor joists began to burn through, followed by falling of safes. The greater number of safes fell in the period between 23 and 38 minutes. When the fire had been burning 28 minutes a section of the front wall of the larger building fell out. Portions of the other walls fell at intervals thereafter, until at the end of the first hour the greater portion of the walls above the first story in the small building and above the second story in the other building had collapsed. When the side walls of the 5-story building fell out, the falling brick work blanketed the 2-story structure and produced a prolonged heat exposure for the buried safes. After 1½ or 2 hours it could be said that the buildings were burned down, but in the larger building there remained a large mass of debris that continued to flame for many hours.

The test involved a large amount of work in preparation, and observation during and after test. A complete report based on a full reduction of temperature and other data cannot be given at this time. However, it can be stated that the temperature rise during the initial portion of the test was more rapid than in the standard furnace test, 2000° F.

obtaining at several points within 20 minutes, and maximums between 2200 and 2400° F. at a few points within 40 minutes. After collapse of floor and roof constructions the air temperatures fell rapidly except at points immediately above the burning debris. The exposure in the ruins was more prolonged although less intense. Temperatures high enough to be prejudicial to the fire safety of the contents of safes obtained in different portions of the ruins for periods from a few hours to three days. The severity of the exposure to different safes varied greatly even in places where the safes were within a few feet of each other in the ruins. The test should therefore not be regarded as being in any sense a comparative fire test of safes, but rather one to determine the fire exposure conditions for such devices. It is expected that the test will yield data among others on the following points:

(1) The rapidity of spread of fire in open joisted buildings of the type tested;

(2) The rate of temperature rise and maximums obtaining before the interior construction collapsed as measured by thermocouples within mountings of size comparable with those employed for furnace temperature measurements in fire tests;

(3) The extent to which the rapid temperature rise produced explosive openings of safes as has been experienced in some fires;

(4) The time the safes dropped, this to be considered in comparison with the one-half hour or one hour duration of fire test before impact drop in the standard procedure for testing safes;

(5) The effect of the drop on the safe structure, and also the effect of impact from falling brick walls and similar heavy objects, this to be considered in comparison with the effect of the 30-foot drop on brick rip-rap in the specification test for safes;

(6) The effect on safe and contents of being covered, partly covered, or in contact with the hot debris after the fire;

(7) The percentage of safes involved that were fully covered, partly covered, in contact with, or clear of the hot debris;

(8) Air temperatures above the debris, this having a bearing on exposure to safes, and to party and fire walls;

(9) Temperature in the debris until cooling down, a matter of several days;

(10) Effect of the fire in producing collapse of building details such as enclosing walls and metal roof covering, the protection afforded neighboring buildings by these details and general hazard to surroundings created by the fire.

It might be added that the test created little hazard to the surrounding buildings with the weather conditions present. The temperature on the exposed wall of a temperary wooden shed located 110 feet from the burning buildings in a position to receive the maximum effect from radiated heat was apparently well below the ignition point for wood. The column of hot gases rose in such manner as to easily clear all surrounding buildings in its path. The only building that it might have affected was the Post Office Department building whose tower is of considerable height. However, the mild breeze present bore the column in a different direction. The test was marked by almost total absence of brand production. This might be owing to the general character of the contents consisting as they did of no lighter material than one inch boards as well as to the absence of wind. The steel roofing in the buildings functioned acceptably in the period 15 to 30 minutes in forcing exit of the hot gases mainly through the window openings, thus preventing a decided chimney effect. The tie rod through the side walls above the roof line apparently delayed major collapse of walls until the fire was a little past maximum intensity, when their fastenings pulled through the masonry. All walls fell outward caused by expansion near the inner surface from the fire. A similar effect has been observed in fire tests of unrestrained walls, although with 12-inch thick walls 11 feet high or 8-inch walls of similar height stiffened with plasters 8 inches thick, the deflections developed were not large enough to cause collapse.

COMMERCIAL STANDARD FOR CLINICAL THERMOMETERS.

WRITTEN acceptances, representing at least 65 per cent. of production by volume, and a majority of distributors and organized users, having been received by the commercial

standards unit of the Bureau of Standards, announcement has been made by the bureau that the commercial standard for clinical thermometers will become effective for the industry on October 1, 1928.

This standard was formally approved by a general conference of manufacturers, distributors and organized users, held March 30, 1928. The conference at that time agreed that production of new thermometers under this standard would begin October 1, 1928, and that one year (March 30, 1929) would be allowed for clearance of existing manufacturer's stocks. Annual revision of the standard was provided for through the appointment of a standing committee, representative of the entire industry.

The industry also authorized the promotion of foreign commerce in this commodity, which will be manufactured under provisions of the standard. It will be first translated into Spanish and Portuguese.

At the time the conference was held manufacturers present stated that the industry was determined to market only accurate and reliable clinical thermometers and to this end each thermometer would be certified by the manufacturer to the purchaser as complying in all respects with the requirements and tests required by the approved commercial standard adopted.

TESTS OF LARGE CONCRETE CYLINDERS.

THE data on the test of the group of concrete cylinders described in *Technical News Bulletin* Nos. 129 and 133 have been carefully analyzed, resulting in some interesting developments. It may be recalled that the cylinders were in the proportion of height equal to twice the diameter, the sizes being 2, 3, 6, 12, 18, 24 and 36 inches in diameter.

Comparison of test results readily showed that in general, throughout the tests, for any batch, the larger the diameter of the cylinder the lower the strength. The several factors influencing the strength were studied. These were: fabricating methods, curing conditions, testing machine speed, proportions and water-cement ratio. The 2-inch and 3-inch cylinders were made by one method, the 6-inch and 8-inch by

another, the 12-inch and 18-inch by another, which was slightly modified when applied to the 24-inch and 36-inch cylinders. It was found that for cylinders of different size and made of the same proportions, and by the same fabricating and curing methods, the strength was practically the same, and conversely every change in strength was accompanied by a change in fabricating method or a change in mix. As one example, the average strength of the 2-inch cylinders, which were of the same material and made in the same manner, by only $\frac{1}{4}$ per cent. The difference in cylinder size was therefore shown not to be responsible for the change in strength.

The rate of deformation of the cylinders varied considerably with the size of specimen, due mainly to the different specimen heights, coupled with the standard head speed. The rate of deformation of the 6-inch cylinders was approximately the rate of the 24-inch cylinders, yet the 6-inch cylinder strength was in each case markedly higher than the strength of the 24-inch cylinders, eliminating the difference in rate of testing deformation as the cause of the strength difference.

Due to the difference in strength of cylinders made from purportedly duplicate batches, the influence of increasing the size of the aggregate in the mix was not unconditionally determined. The best indications from the tests, however, are that the maximum strength is attained under the fabricating conditions of this group of test cylinders, with aggregate of maximum size of about two inches, the strength falling off with increase in size of aggregate. The strength with 10-inch aggregate is approximately 20 per cent. less than for 2-inch aggregate. The loss in strength may be reasonably allocated to the difficulty of causing the larger aggregate to be interlaid in the minimum volume, or with a minimum of voids.

USES OF GLUE IN THE PAPER INDUSTRY.

A HANDBOOK on the above subject, recently published by the Glue Research Corporation, contains a summary of the information gathered during the investigation of the uses of glue in the paper industry, by the research fellowship of the National Association of Glue Manufacturers at the Bureau of Standards. This was prepared by G. K. Hamill, research associate of the glue association who conducted the work.

The publication contains an outline of papermaking processes in general, information on uses of glue in beater sizing, surface sizing and coating, and a bibliography of publications dealing with these subjects.

Copies may be obtained from the Glue Research Corporation, 1457 Broadway, New York, N. Y.

TESTING PROCEDURE FOR DESTRUCTIVE AGENTS ON DETERIORATED COTTON TEXTILES.

DETERIORATED textile fabrics and yarns frequently present a very difficult problem to the textile chemist. This is especially so in the case of laundry materials where often accumulative deterioration occurs and the destructive agent is almost entirely removed by the laundry process. The problem then is the detection, identification, and estimation of chemicals of microscopic size.

The technical literature discloses that general methods are available for the most likely destructive agents. Other methods dealing more specifically with textiles are to be found in technical and trade publications in the textile field.

In connection with a study of deteriorated textiles it was necessary to formulate a procedure for estimating the maximum number of possible destructive agents with a minimum of sample available.

This procedure covers the analysis of a deteriorated cotton textile fabric for total silica, iron, aluminum, sulphates, total acidity, oxalates, soluble sulphates, soluble chlorides, and combined chlorides.

CHROME AND VEGETABLE TANNED SHEEP LEATHERS.

In connection with studies of the properties of leather six sheep skins were prepared by a tanner for the purpose of noting the effect of chrome and vegetable tanning processes on the strength and stretch of these leathers. Each skin was split down the back and one side of each skin was tanned by the vegetable process while the remaining sides were tanned by the chrome process. Each side of leather was cut into strips 1 x 6 inches, each of which was tested for strength and stretch. The results are listed below.

Sample.[1]	Tannage.[2]	Average thickness.	Percentage of stretch		Tensile strength.	Direction.[3]
			at 1000 pounds per square inch.	at failure.		
		inches			lbs./in.	
1	C	0.035	—	47.0	2915	L
4	C	.038	—	42.0	3440	L
5	C	.034	25.5	43.8	2440	L
1A	V	.037	—	37.2	3325	L
4A	V	.044	—	36.5	4125	L
5A	V	.038	18.2	35.3	2995	L
2	C	.039	64.7	90.2	2305	C
3	C	.030	—	90.0	2120	C
6	C	.029	—	80.7	1595	C
2A	V	.038	61.4	85.8	2355	C
3A	V	.036	—	76.5	2515	C
6A	V	.031	—	87.3	1755	C
			SUMMARY.			
1A–4A–5A	V	0.040	—	36.3	3495	L
2A–3A–6A	V	.035	—	82.9	2280	C
1–4–5	C	.036	—	44.3	2900	L
2–3–6	C	.032	—	86.8	1995	C

[1] 1 and 1A, 2 and 2A, etc., sides of the same skin.
[2] C—Chrome, V—Vegetable.
[3] Direction of cutting test pieces, L—Lengthwise, C—Crosswise.

It will be noted that the sheep leather is much stronger in the lengthwise direction than in the crosswise direction regardless of the type of tannage and that the percentage of stretch is approximately double in the crosswise direction. The finishing methods may have an influence on these properties. The vegetable tanned leathers are stronger and stretch less than the chrome tanned leathers.

NOTES FROM LIGHTING RESEARCH LABORATORY, NATIONAL LAMP WORKS OF GENERAL ELECTRIC COMPANY.*

PHOTO-ELECTRIC SPECTROPHOTOMETRY.[1]

By A. H. Taylor, Physicist.

SPECTROPHOTOMETRY by visual methods is limited in accuracy by many experimental difficulties. This is especially true with respect to light near the ends of the visible spectrum, where the visibility of radiation is low.

In order to overcome these difficulties the author has adapted a photo-electric cell and vacuum-tube amplifier to a Hilger constant-deviation spectroscope. The image of a ribbon-filament tungsten lamp is focussed on the collimater slit, which is adjusted to a width of 0.2 mm. The eyepiece was altered to provide a 0.27 mm. slit, and a light-tight cabinet containing a gas-filled cæsium photo-electric cell is placed over the end of the telescope. Between the dispersing prism and the ocular telescope a housing was built. This contains a movable 45° mirror by means of which an opal-glass disk immediately above is imaged in the ocular telescope. Above this opal-glass is placed a movable tungsten lamp which illuminates it. The range of movement of this lamp is sufficient to make a change of 6 to 1 in the illumination on the opal-disk. Additional range is provided for by a sectored disk placed between the ribbon-filament lamp and collimater slit.

The cathode of the photo-electric cell is connected to the grid of a UV-199 vacuum tube. The anode is connected to the negative-end of the filament through a 180-volt B battery, 45 volts of which are also used to supply the plate current. In the plate circuit is placed a 12,000 ohm rheostat, and a galvanometer and battery are connected between one end and the slider of this rheostat. When the voltage drop between these two points is just equal to the voltage of the battery in

* Communicated by the Director.

[1] To be published in full in the Jour. Opt. Soc. Am. and Rev. of Sci. Inst.

the galvanometer circuit, no current flows through the galvanometer.

When making a photometric balance the photo-electric cell is first exposed to the monochromatic light, and the rheostat is adjusted to make the galvanometer current approximately zero. Then the 45° mirror is moved into position to obscure the monochromatic light and substitute the image of the opal-glass disk. The movable lamp is adjusted until the galvanometer deflection is the same as before. If the balance remains unchanged when the monochromatic light is again exposed, the distance of the lamp from the opal glass is read off from a scale. When the spectral transmission of a colored glass is to be measured, the glass is placed between the ribbon-filament lamp and the collimater slit. Photometric balances are made at desired wave-length intervals with and without the glass interposed.

Measurements have been made on a number of color-filters which had previously been measured by the Colorimetry Section of the Bureau of Standards, with very satisfactory agreement in most cases. The sensitivity is sufficiently high to make measurements throughout the wave-length range from 4000 Å. to 7600 Å., and to measure with fair accuracy transmission-factors below one-half of one per cent., which would be practically impossible by visual methods. Very careful electrical shielding is necessary in order to obtain good results.

THE RELATION OF INTENSITY OF ILLUMINATION TO COLOR DISCRIMINATION.

By M. Luckiesh, Director.

THE appearance of a colored object is not fixed or invariable. It depends primarily upon the spectral character of the illuminant and spectral reflection of the object; and secondarily upon many other factors such as contrast, brightness, size, etc. For the purpose of color-standardization we contend that white light should be used. Rarely, however, is anyone interested in a color for itself and by itself. Nearly always the color of an object is significant only relative to that of another object. In color-grading the object is compared with an arbitrary standard.

In most cases of color-grading, any illuminant fairly rich in visible radiation of all wave-lengths is satisfactory if the level of illumination is sufficiently high. The level of illumination is a very important factor in color-work which has been unduly submerged by considerations of color quality alone. However, experience has shown us that, in most of the cases of color-grading in industry, it would be better to have a large amount of light of fair quality or spectral character than to have a meager amount of light of a daylight quality.

We have recommended an illuminant approximating daylight for the color-grading of many kinds of products, and have specified levels of illumination running into hundreds of foot-candles. For example, there are paint shops using 50 foot-candles, and in a tile factory color-grading is being done under 150 foot-candles. On every hand it appears that there are color problems which can be solved in this manner.

We recently recommended a lighting installation for a factory where fifty operators are engaged in color-grading of moderately dark, glossy buttons. Background is important in such work and we found a dull black to be best. Owing to specular reflection from the buttons, diffused light or light from a large source close to the work was unsatisfactory. We found that fairly concentrated light from one side, or both sides, minimized the annoyance of specular reflection. After experimenting with various natural and artificial illuminants, we concluded that the best level of illumination for these buttons, of low reflection-factor, was in the region of 300 to 500 foot-candles, and that the quality of light from tungsten Daylight lamps was satisfactory. As a result, we recommended a minimum of 100 foot-candles (preferably 200 or 300 foot-candles) obtained with tungsten Daylight lamps.

THE DURATION OF CLOSE VISION IN VARIOUS KINDS OF WORK.

By M. Luckiesh, Director.

PRODUCTION increases in our offices and factories when the level of illumination is increased, chiefly because the worker sees more quickly and with greater certainty than under low levels of illumination. Seeing is a partnership of vision and

lighting. Vision is the internal partner over which we have little control. Lighting is the external partner over which we have full control. In our study of lighting and its relation to vision, we find that improvements in lighting (increased levels of illumination, reductions of glare, increased contrast, etc.) increase the speed and accuracy of vision. However, in considering the influence of lighting on production, the question arises, "What percentage of the time does a worker actually use his eyes for close vision?"

In twenty industrial and office processes which we investigated, the average portion of time during which the eyes of the worker are engaged in close work was found to be about 70 per cent. These processes are found in ordinary offices, print shops, machine shops, and electric lamp factories. Obviously, some processes require the use of the eyes very much of the time, while others do not tax them so much. In only six of the twenty processes did the percentage of time requiring close vision fall below 50 per cent.; only three fell below 40 per cent.; and five were above 70 per cent.

These data indicate, as was to be expected, that increases in production, due to improvements in lighting, are likely to be different for various processes. They indicate further that close vision is required for a considerable percentage of the time in any of these representative processes, and that we may expect an appreciable increase in production from improved lighting in all our industrial processes where vision is required. Moreover, it is made clear by these experiments that increases in production already noted in factory tests are conservative values and should be easily equalled in most cases and exceeded in many.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE ELECTRICAL DEPOSITION OF RUBBER.[1]

By S. E. Sheppard.

THE negative charge on rubber particles corresponds to a contact potential of about 0.035 volt, and the particles have a mobility of about 2.7×10^{-4} cm. per second. The relation $n = c/k$, where n is the amount of rubber transported toward the anode per unit of current, c is the concentration of rubber in the latex, and k is the total conductivity of the latex, is approximately obeyed. To avoid porous deposits caused by the evolution of oxygen at the anode, depolarizers may be used. Fresh deposits are permeable, therefore thick coatings may be built up. Fillers, in the form of colloidal suspensions, are added to the latex, and are deposited along with the rubber.

NOTE ON A NEW EFFECT OF CHROMIC ACID DESENSITIZER.[2]

By E. P. Wightman and S. E. Sheppard.

CERTAIN plates made with inert gelatin were treated with chromic acid solution for Mr. A. P. H. Trivelli who observed that they apparently showed fog and sensitivity increase above the untreated plate. This phenomenon has been investigated further and it has been found that the increase in sensitivity passes through a maximum with time of treatment and finally for treatments of four hours or longer there is a small desensitizing effect. The phenomenon disappears when the plates are washed thoroughly in rapid running water prior to desensitizing. The effect may be due (1) to the liberation of bromine from soluble bromide in the plate by the chromic-sulfuric acid, on which bromine may act, according to a

* Communicated by the Director.

[1] Communication No. 320 from the Kodak Research Laboratories and published in *Trans. Amer. Electrochemical Soc.* **52**: 47 (*1927*).

[2] Communication No. 339 from the Kodak Research Laboratories and published in *Phot. J.*, **68**: 201 (*1928*); *Sci. Ind. Phot.*, **8M**: 21 (*1928*).

hypothesis proposed by Hickman (*Phot. J.*, **67**: *34. 1927*) and E. P. Wightman and R. F. Quirk (*J. Frank. Inst.*, **204**: *731. 1927*); (2) to a lessening of the number of competing sensitivity specks by the chromic acid thus allowing the remaining specks to be more effective; or, (3) the specific action of chromic acid on something in the gelatin giving rise to a new sensitizer.

Acid permanganate does not produce the effect. This effect will be studied over a wider range of conditions.

THE FRANKLIN INSTITUTE.

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NECROLOGY

Mr. Paul Didier, Pittsburgh, Pa.
Mr. Herbert Lloyd, Philadelphia, Pa.
Col. J. A. Steinmetz, Philadelphia, Pa.

LIBRARY NOTES.

Recent Additions

American Concrete Institute. Proceedings of the Twenty-fourth Annual Convention, 1928. Volume 24. 1928.
BOREL, ÉMILE. Leçons sur les Séries Divergentes. Deuxième édition. 1928.
CHAZY, JEAN. La Théorie de la Relativité et la Mécanique Céleste. Tome I. 1928.
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HOFFMAN, JAMES D., AND LYNN A. SCIPIO. Elements of Machine Design. 1928.
KINGZETT, C. T. Chemical Encyclopædia. Fourth edition. 1928.
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BOOK REVIEWS

WIRELESS DIRECTION FINDING AND DIRECTIONAL RECEPTION. By R. Keen, B.Eng. (Hons.) Sheffield, A.M.I.E.E. Second and enlarged edition, 490 pages, 21 x 14 cm., cloth. London, Iliffe and Sons. Price, 21 shillings.

From a subject of deep theoretical interest since the classic researches of Hertz, directional wireless transmission is developing into a problem of rapidly increasing practical importance. Directional reception and direction finding as an aid to navigation, once perfected, it is generally conceded, will eliminate much of the hazard to navigation from the presence of fog or other causes which interfere with nautical observations.

Following a historical summary, the directional properties of aërial systems are first analyzed. Passing to the loop systems of modern direction finding, the installation, circuits and characteristics of the forms in which these systems are employed are discussed fully, among these the Bellini-Tosi system which employs two fixed loops at right angles to each other connected to a small loop radio-goniometer with which the readings are made. Besides the purely electrical features much attention is given the geometry of position finding and to maps adapted to those requirements. A chapter also is devoted to field and nautical astronomy. Among other important divisions of the subject which are critically examined are beacon transmitters, various transient phenomena, shore, ship and aircraft direction-finding installations. A bibliography to which references are made in the text is arranged in chronological form at the end of the volume. Especial mention should be made of the numerous diagrams and illustrations. Some of the latter are half-tone photographs, others are pen and ink sketches of unusual descriptive value and clearness. The chapter on tube amplifiers which was included in the first edition is omitted, the subject having outgrown available space. Nevertheless the work contains a comprehensive discussion of the essential elements of wireless direction finding and directional reception.

LUCIEN E. PICOLET.

MEMORIAL DES SCIENCES PHYSIQUES PUBLIÉ SOUS LE PATRONAGE DE L'ACADÉMIE DES SCIENCES DE PARIS, DES ACADÉMIES DE BELGRADE, BRUXELLES, BUCAREST, COÏMBRE, CRACOVIE, KIEV, MADRID, PRAGUE, ROME, STOCKHOLM, etc., etc., Directeurs: Henri Villat et Jean Villey.

Fascicule I, La Mecanique ondulatoire par Louis de Broglie Docteur ès Sciences. 54 pages, 25 x 16 cm., paper. Price, 15 francs.

Fascicule II, La Télémétrie Monostatique par Armand de Gramont, Docteur ès Sciences. 64 pages, 25 x 16 cm., paper. Price, 15 francs, Paris, Gauthier-Villars et Cie, 1928.

In many quarters, publishers of scientific works in recent years have been issuing series of monographs on various topics relating to some particular department of science, the whole forming a collection of encyclopedic character. Messrs. Gauthier-Villars have been very active in that field for many years, their Encyclopédie Scientifique des Aide-memoire, and the collection Scientia being well known to American readers. The project of the present series, their latest contribution of this kind, includes some seventy volumes each on a different topic of physical science under the general title *Mémorial des Sciences Physiques*. They form a

companion series to the previously established *Mémorial des Sciences Mathématiques* devoted exclusively to mathematical subjects of a most advanced type. These volumes are not original memoirs but rather a critical exposition of the latest progress and present state of the subject under discussion. The two volumes above noted are the first of the series to appear.

Doctor de Broglie's contribution deals with the abstract concepts of the wave-motion mechanics according to modern ideas of space and time. He shows how it has given new meaning to dynamic phenomena, the service it has rendered in the physics of the atom and how it constitutes a new mode of attack upon those profound problems already approachable by the theory of relativity. The volume constitutes a profound analysis and development of the ultra-modern concepts of mechanics which are applicable to the new atomic theory.

Doctor de Gramont's subject is of a more tangible character. Telemeters or range-finders are an indispensable part of the equipment of modern warfare which have assumed a variety of forms in the course of the development of a practical and accurate instrument adapted to the exacting service of field conditions. The work in general is devoted to the description of the optical system and its functioning of the short-base telemeter now widely used in all branches of artillery service. Several forms of these telemeters are described with an explanation of their optical systems, methods of calibration and practical data.

L. E. P.

A TEXTBOOK OF ORGANIC CHEMISTRY. By Joseph Scudder Chamberlain, Ph.D., Massachusetts Agricultural College. Second Edition Revised, 901 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1928. Price, $4.

The author who attempts to include in one moderate sized volume a comprehensive summary of organic chemistry has no easy task. He suffers really from the embarrassment of riches, for the amount of information now available concerning both the natural and artificial substances included under the term "organic" is enormous and is increasing with accumulating rapidity. The present volume contains a very large amount of information on all the important departments of organic chemistry. Of recent years the extensive development of bio-chemistry, as it has been called, especially in its applications to physiology and pathology has compelled a separation from the general chemical literature into specialized manuals for use more particularly in medical schools. Incidentally it may be mentioned, though it has no great relevancy to the present criticism, that a strong tendency has been developed to assign the teaching of bio-chemistry and the writings of its textbooks to those having degrees not in medicine but in science or philosophy. We find as a result of this that a considerable proportion of the faculties of our leading medical schools contain teachers that have not been trained in medical science. It is not appropriate to discuss here the advisability of this method. It is being carried out, and until some definite result, favorable or unfavorable, is manifested it will be unwise to give a positive opinion.

Turning to the work in hand which, being a second edition, has thus given evidence of its suitability, the descriptive matter begins as might be expected with that well-known typical molecule, methane, "the baby figure of the giant

mass of things to come." Practical information is scattered liberally through the volume in connection with the descriptions of compounds and the development proceeds as usual in textbooks of this character. A noticeable point of difference which will probably be noted more and more in manuals of this type is the treatment of the proteins in connection with the amino-acids following immediately after the starches and sugars. Heretofore we have always had these complex compounds treated at the end of the volume, often somewhat superficially because the great majority of chemists are only superficially familiar with them. Research has brought these proteins much more into the light as regards composition and we may expect much greater information from the active research now being pursued.

The volume presents therefore a very satisfactory account of all the basic phases of organic chemistry and will serve well for the student in that field. It is excellently printed with extensive presentation of structural formulas, a detailed table of contents and a good index.

HENRY LEFFMANN.

LEÇONS SUR LES SÉRIES DIVERGENTES. Par Émile Borel, Membre de l'Institut, Professeur à la Sorbonne, Directeur honoraire de l'École normale supérieure, avec le concours de George Bouligand, Professeur à la Faculté des Sciences de Poitiers. Second edition, 260 pages, 25 x 16 cm., paper. Paris, Gauthier-Villars & Cie., 1928. Price, 40 francs.

The influence of Professor Borel's "Leçons" which first appeared in 1901 has done much to stimulate activity in the study of divergent series and their application. In preparing this second edition, M. Bouligand has adhered to the general plan of the original work, yet including an account of recent progress in setting forth the origin of the processes of summation, their general characteristics and the conditions for their concordance. Stress has been laid on applications which reveal the relation of the subject to other theories of analysis. For example in the third chapter a consideration of trigonometric series brings into view two ideas which are essential to the foundation of summation processes, namely, mean value and factors of convergence. The work is addressed to the pure mathematician rather than to the reader who seeks directly applicable mathematical data. Beginning with a historic general review, the chapter headings are: I. Asymptotic series. II. Continued fractions and the theory of Stieltjes. III. The theory of summable series. IV. Summable series and analytical expansion. V. Expansion in series of polynomials. VI. (Appendix) Modern Development of the theory of divergent series. L. E. P.

THE A. C. COMMUTATOR MOTOR. By C. W. Olliver, B.Sc., E.S.E. (Paris). xi-281 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, 1927. Price, $7.50.

The alternating-current system as a method of power-supply with its intercommunicating net-work which now include wide areas of service is gradually eliminating the direct-current motor from the field of quantity-supply and with it, the sometimes inevitable but often avoidable commutator trouble. The one important exception is in railway engineering where the direct-current motor still prevails, but part of this condition, the author suggests, may be chargeable to "bureaucratic engineering," not uncommon in public utility organizations.

Whatever may be the surrounding circumstances and causes, the alternating current has come very much into its own and it is in order to provide motors that are capable of utilizing this current which have the same desirable flexibility and efficiency as has been attained in the direct-current motor.

The author believes that the alternating-current commutator motor affords an almost perfect solution to the problem, not perhaps so much by itself as when combined with the more usual induction motor. His book is in two distinct parts. The first contains all the analytical treatment of the subject while the second is devoted to a non-mathematical exposition of the principal applications of the commutator motor. After an introductory review, a study of commutation at considerable length is made. Having surveyed this important detail which the author believes has caused unfounded prejudice against the A. C. commutator motors, he proceeds to the theory of the simpler forms of single-phase and repulsion commutator motors. This analytical treatment covering the polyphase motor as well. The next chapter dwells upon the characteristics of the three-phase motor and explains as simply as possible what actually takes place in a machine of that kind. Then follows a chapter on cascaded sets and power-factor correction which includes a study of the influence of the power-factor, an analytical study of the induction motor and commutator motor combination, a description of various compensated motors and recent developments in power factor correction and speed regulation of induction motors. The second part on practical applications covers a well illustrated account of applications to cranes and hoisting appliances, single phase traction, the application of commutator motors to rolling-mill drives and to a number of other typical purposes. Both the analytical part and the descriptive matter represent the latest advances made by continental engineers and their methods of analysis. Much of the analytical matter and the project of writing this illuminating treatise were inspired, the author states, by lectures of Professor Marius Latour at the Ecole Superieure d'Electricite of Paris. L. E. P.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 282. The Performance of Several Combustion Chambers Designed for Aircraft Oil Engines, by William F. Joachim and Carlton Kemper. 12 pages, illustrations quarto. Washington, Government Printing Office, 1928. Price, 10 cents.

Several investigations have been made on single-cylinder test engines at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics to determine the performance characteristics of four types of combustion chambers designed for aircraft oil engines. Two of the combustion chambers studied were bulb-type precombustion chambers, the connecting orifice of one having been designed to produce high turbulence by tangential air flow in both the precombustion chamber and the cylinder. The other two were integral combustion chambers, one being dome-shaped and the other pent-roof-shaped. The injection systems used included cam and eccentric driven fuel pumps, and diaphragm and spring-loaded fuel-injection valves. A diaphragm-type maximum cylinder pressure indicator was used in part of these investigations with which the cylinder pressures were controlled to definite values. The performance of the engines when equipped with each of the combustion chambers is discussed. The data presented show the performance for speeds from 600 to 1,800 R.P.M.

The results obtained indicate that aircraft-type oil engines with suitably designed combustion chambers and fuel-injection systems may be operated at speeds around 1,800 R.P.M. without encountering excessive explosion pressures. At a speed of 1,600 R.P.M. and with a fuel quantity giving 15 per cent. excess air in the cylinder, a maximum I.M.E.P. of 119 pounds per square inch was obtained with a fuel consumption of 0.43 pound per I.HP. per hour. The maximum cylinder pressure was 740 pounds per square inch. A minimum fuel consumption of 0.26 pound per I.HP. per hour at an I.M.E.P. of 52 pounds per square inch and 1,600 R.P.M. was obtained with a cylinder head having a bulb-type precombustion chamber. The maximum cylinder pressure was 560 pounds per square inch.

It is concluded that an increase in the specific power output of the high-speed aircraft oil engine depends upon the ability to obtain higher mean effective pressures and an improvement in the mechanical efficiency of the engine. The best performance for the tests reported was obtained with a bulb-type combustion chamber designed to give a high degree of turbulence within the bulb and cylinder.

Report 283, A Preliminary Investigation of Supercharging an Air-Cooled Engine in Flight, by Marsden Ware and Oscar W. Schey. 11 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, ten cents.

This report presents the results of tests made by the National Advisory Committee for Aeronautics in a preliminary investigation of the effects of supercharging an air-cooled engine under airplane flight conditions.

This investigation comprises the first of its kind that has been conducted and for which results have been published.

Service training airplanes were used in the investigation equipped with production types of Wright J engines. An N.A.C.A. Roots type supercharger was driven from the rear of the engine.

In addition to measuring those quantities that would enable the determination of the climb performance, measurements were made of the cylinder-head temperatures and the carburetor pressures and temperatures. The supercharging equipment was not removed from the airplane when making flights without supercharging, but a by-pass valve, which controlled the amount of supercharging by returning to the atmosphere the surplus air delivered by the supercharger, was left full open.

With the supercharger so geared that ground-level pressure could be maintained to 18,500 feet, it was found that the absolute ceiling was increased from, 19,400 to 32,600 feet, that the time to climb to 16,000 feet was decreased from 32 to 16 minutes, and that this amount of supercharging apparently did not injure the engine.

Report No. 284, The Comparative Performance of Roots Type Aircraft Engine Superchargers as Affected by Change in Impeller Speed and Displacement, by Marsden Ware and Ernest E. Wilson. 14 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, ten cents.

This report presents the results of tests made by the National Advisory Committee for Aeronautics on three sizes of Roots type aircraft engine superchargers.

The impeller contours and diameters of these machines were the same, but the lengths were 11, 8¼, and 4 inches, giving displacements of 0.509, 0.382, and 0.185 cubic foot per impeller revolution. The information obtained serves as a basis for the examination of the individual effects of impeller speed and displacement on performance and of the comparative performance when speed and displacement are altered simultaneously to meet definite service requirements.

According to simple theory, when assuming no losses, the air weight handled and the power required for a given pressure difference are directly proportional to the speed and the displacement. These simple relations are altered considerably by the losses.

When comparing the performance of different sizes of machines whose impeller speeds are so related that the same service requirements are met, it is found that the individual effects of speed and displacement are canceled to a large extent and the only considerable difference is the difference in the power losses which decrease with increase in the displacement and the accompanying decrease in speed. This difference is small in relation to the net power of the engine supercharger unit, so that a supercharger with short impellers may be used in those applications where the space available is very limited without any considerable sacrifice in performance.

Report No. 286, Aërodynamic Characteristics of Airfoils—V. 49 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, twenty-five cents.

This collection of data on airfoils has been made from the published reports of a number of the leading aërodynamic laboratories of this country and Europe.[1] The information which was originally expressed according to the different customs of the several laboratories is here presented in a uniform series of charts and tables suitable for the use of designing engineers and for purposes of general reference.

It is a well-known fact that the results obtained in different laboratories, because of their individual methods of testing are not strictly comparable even if proper scale corrections for size of model and speed of test are supplied. It is, therefore, unwise to compare too closely the coefficients of two wing sections tested in different laboratories. Tests of different wing sections from the same source, however, may be relied on to give true relative values.

The absolute system of coefficients has been used, since it is thought by the National Advisory Committee for Aëronautics that this system is the one most suited for international use and yet it is one from which a desired transformation can be easily made. For this purpose a set of transformation constants is given.

Each airfoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for designing purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent. of the chord length, the latter also serving as the datum line. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration, the outside of the heavy line representing the profile.

The authority for the results here presented is given as the name of the

[1] A previous collection of airfoil sections numbered 1 to 623 and Charts 1 to 16 may be found in N. A. C. A. Reports Nos. 93, 124, 182, and 244.

laboratory at which the experiments were conducted, as explained under abbreviations, with the size of model, wind velocity, and year of test.

LA THÉORIE DE LA RELATIVITÉ ET LA MÉCANIQUE CÉLESTE, Par Jean Chazy, Chargé de Cours à la Faculté des Sciences de Paris. Vol. I, viii–261 pages, 25 x 16 cm., paper. Paris, Gauthier-Villars & Cie., 1928. Price, 60 francs.

The aim of this work, which is the development of a course of study at the Faculté des Sciences de Paris in 1927, is to set forth as clearly as possible the theory of relativity in its relation to celestial mechanics assuming on the part of the reader the preparation of a student who has followed courses in the differential calculus and in mechanics.

The first chapter deals with the elements of the calculus of variations, a method to which the usual courses of instruction give no attention, and the definition and conceptions concerning such quantities as ds^2 which enter into the current anguage of the theory of relativity. In the second chapter the author states the law of gravitation reckoning from the ds^2 of Schwarzschild. Applying this law to movements of the planets with respect to the sun, he calculates the advancement of the corresponding perihelia and obtains notably the celebrated value 42.9 seconds per century for the planet Mercury. In the third chapter, the author adopts the law of gravitation thus defined to the method of the variation of the constants under the classical form of the theory of perturbations. He examines analogous laws of gravitation stated in classical mechanics to explain the observed advancement of the perihelion of Mercury. He studies the corrections to duration of newtonian revolutions and more particularly applies these corrections to the passage of Mercury over the solar disc.

The fourth and fifth chapters, due to a digression justified by the purpose of the work, are devoted, the one to a résumé of the investigations of Le Verrier and of Newcomb relating to the errors of the movements of planets with relation to the newtonian theory, the other to an exposé of the different hypotheses advanced to explain the three disagreements obtained by Newcomb. The last chapter covers the examination of the law of the propagation of light defined by the ds^2 of Schwarzschild from which is derived the remarkable result of 1.74 seconds for the deviation of luminous rays tangent to the solar globe.

A second volume will dwell particularly upon the origin of the ds^2 of Schwarzschild and how Einstein was led to formulate the law of gravitation defined by this ds^2. He will calculate other different effects of the theory of relativity which can be compared with observations in a more or less proximate future, of the effect of rotation of the central body upon the movement of a mass gravitating in its vicinity, the movement of precession along the orbit of the Earth, and cosmological applications.

L. E. P.

REPORT OF THE COMMISSION APPOINTED TO INVESTIGATE THE FAILURE OF THE ST. FRANCIS DAM. 21 pages, 30 plates, 8vo. Sacramento, California State Printing Office, 1928.

The failure of the St. Francis Dam in California added one more to the long list of serious disasters from such constructions. The Commission appointed by the Governor of California to investigate the cause and course of the disaster has presented in this pamphlet a full detailed account. This information will be of

great value and importance to engineers engaged in the construction of such works, which are becoming more and more necessary in our modern industrial and city life. The necessity of impounding large masses of water for general supply and power purposes is now great.

The verdict of the Commission is that the dam itself was properly constructed but that the natural-rock foundation was defective, being composed partly of a mica schist of inferior firmness.

H. L.

CHEMICAL ENCYCLOPÆDIA. By C. T. Kingzett, F. I. C., F. C. S. 8vo, vii–807, illustrations. D. Van Nostrand Company, New York, 1928. Price, $10.

The fact that this work has gone to the fourth edition within comparatively brief time shows that it has met a very important want in chemistry, and that it has merit. The great development of industry in chemistry has caused a material increase in the size of the volume, about two hundred pages having been added as compared with the third edition. Care and attention has been given to corrections that have been necessary and matters relating to chemical applications and chemical engineering have been incorporated. A broad field has been covered since the text includes items of pure, physical and applied chemistry, together with general descriptions of both inorganic and organic compounds, and the more important chemical terms and theories.

In consequence of the comprehensive character the work is valuable, not only to professional chemists in both the research and commercial phases, but also to lawyers and other professional persons who may be engaged in litigation or discussions in which chemical questions arise. It is stated in the preface that there is no other work in existence that gives such an extensive range of condensed up-to-date information concerning chemistry and industry. It is well printed and well written. It is much to be regretted that the great increase in the cost of printing compels publishers to place such high prices upon books of this character.

HENRY LEFFMANN.

PRINCIPLES OF MECHANISM. By F. Dyson, A.C.G.I., B.Sc. (Hons.), A.M.I., Mech.E., Lecturer in Mechanical Engineering at the City and Guilds (Engineering) College, Imperial College of Science & Technology, London. viii–296 pages, 21 x 14 cm., cloth. Oxford University Press, American Branch, New York, 1928. Price, $4.25.

The design of a machine is always a tentative process in which the choice of the component mechanisms rests with the judgment of the designer. There is no analytical process to guide the selection of the most suitable mechanism to effect a required motion, but a sound knowledge of the principles which govern the operation of simple mechanism is the nucleus, about which a vast collection of amplification may be derived.

The present author has not adhered strictly to purely kinematical principles. He has judiciously introduced some dynamical ideas which, if they depart from the strict orthodoxy of pure mechanism, aid materially in giving the exposition of the subject a practical meaning of applicable value. Most of the usual topics found in works on mechanism which deal with the abstract consideration of

motions apart from the forces which accompany them are included. Here, force, work and friction are considered and applied to an explanation of the efficiency and non-reversibility of mechanisms. Velocity and acceleration determinations are described of a variety of linkages adequate to ordinary demands, tooth gears, ordinary and epicyclic trains receive a very satisfactory condensed treatment. Among the examples of epicyclic trains is discussed the Ford two-speed reverse gear, and other trains of that type. Belts, pulleys, friction, fly wheels, governors, cams and balancing receive an equal amount of attention. Worked-out examples constitute an important feature of the text and in addition a liberal number of examples of practical character is provided at the end of each chapter. Without being exhaustive in character, this book represents a thorough and rational treatment of the principles which govern the functioning of mechanisms.

LUCIEN E. PICOLET.

ELEMENTS OF MACHINE DESIGN. By James D. Hoffman, M.E., and Lynn A. Scipio, M.E. 327 pages, illustrations, 21 x 14 cm. Boston, Ginn & Company, 1928. Price, $3.80.

A number of treatises on machine design are already extant which very fully and satisfactorily to many classes of readers treat the details of the subject. The appearance of another work must be to meet some particular curriculum requirements or should possess some very marked advantage of arrangement of subject matter. The principal objective of this work, the authors state, is to illustrate by the use of typical examples of design, methods of attack whereby the student may most expeditiously derive the greatest amount of information.

The book is in two main divisions. In the first, fundamental principles of machine design are laid down. The second division is devoted to design applications of the principles which are discussed in the first division. The first part includes a generally satisfactory presentation of the usual topics of machine design. There is a large amount of descriptive information, and the formulas used are stated without derivation but adequately explained by illustrative examples. Reference to active works direct the reader to whatever further analytical information may be desired. A discussion of springs for some reason not stated has been entirely omitted. The second part includes examples of toggle-joint presses, designs of a punching and shearing machine, an overhead travelling crane, a Scotch boiler and a number of diagrammatically illustrated assignment sheets for the exercise of inventive capacity. Some of these appear a bit ambitious for a novice. Thus several forms of bent wire paper clips in common use are shown. The problem calls for the design of cams, connecting levers and properly shaped dies to produce from a spool of wire the forms indicated. The work appears to be an adaptation of less analytical character of the first-named author's earlier work on the same subject in collaboration with Professor Charles H. Benjamin. The subject is generally well covered and should prove an efficient text for school work, but there are many individual readers who would derive greater profit from the type-forms of standard machines illustrated in fuller detail. An album of typical structural detail of modern machines used in manufacturing is indeed more urgently needed by the student of machine design than another book on the principles of the subject.

LUCIEN E. PICOLET.

THE ESSENTIALS OF TRANSFORMER PRACTICE, THEORY, DESIGN AND OPERATION. By Emerson G. Reed, Bachelor of Science in E.E., Member of the American Institute of Electrical Engineers. An Associate Editor of Pender's Handbook for Electrical Engineers. Second Edition, Revised and Enlarged, 401 pages, illustrations, 22 x 14 cm., cloth. New York, D. Van Nostrand Company, Inc., 1927. Price, $5.

Like other components of the almost universally used alternating current system, the transformer has received its due share of analysis and refinement. Theoretical and practical questions over a long term of years of development have been settled and processes of design have assumed the stable conditions of an important industry. A code of practice of the processes of design and proved methods of operation of these apparatus is accordingly desirable and possible and the authors' presentation of a systematic and deductive account of the theory of the transformer, its design and operation is an adequate response to a need of a logical guide for the designing or operating engineer or for the student.

Both in topic and treatment, the book is of a type that will prove especially useful to those who desire rational methods in specific problems of design. There are numerous diagrams and charts but no illustrations of apparatus. Such illustrations useful as they are in surveying the field of previous accomplishments could scarcely be included without unduly increasing the size of the volume, besides the designing engineer usually has such information on file; the student must have recourse to periodical literature, trade publications or other descriptive sources for structural detail.

A condensed historical review precedes the discussion of the subject proper. After surveying the general principles of the transformer and defining the relation of impressed and delivered electromotive forces and primary and secondary currents, the author discusses copper and iron losses and relations derivable from these losses. These analyzed, the results are applied to the deduction of relations of losses to the cost of a transformer. The next step is a consideration of type (shell or core) and the effect of changing the proportions of a transformer. The application of these principles is now made to carrying out in detail the design of various types of transformers in which the tabulated results of six different computations are given for a transformer of given capacity with variant values of coefficients previously discussed. Many other topics, among them efficiency, regulation, heating, insulation and mechanical stresses are treated in the same thorough fashion as the preceding.

The liberal number of numerical examples which are included throughout the work to illustrate the analytical deductions are helpful to almost any class of readers and especially to students. There are few references to original papers and no bibliography, an adjunct of recognized utility in modern technical works. A small amount of space might with advantage have been devoted to a key to the notation employed to facilitate the use of the work as a reference manual.

L. E. P.

FIXATION OF ATMOSPHERIC NITROGEN. By Frank A. Ernst, Fixed Nitrogen Research Laboratory, U. S. Department of Agriculture. 154 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. Price $2.50.

Nitrogen is a sort of Doctor Jekyll and Mr. Hyde among the familiar gases. Inert in its free state as it is in the atmosphere, it shows a wide range of chemical activities in combination. Its compounds are extremely numerous and of very varied characters, in some cases, for instance, strychnine, the compound may be permanent, but in the common high explosives we have extreme susceptibility to violent action. The element is an important one in biologic chemistry, essential to the formation of tissues in animals and plants. It has therefore functioned largely in agriculture and it has been found that one of the most useful forms is as nitrate. The world has relied for many years upon the remarkable and extensive deposits of sodium nitrate in the rainless area of Chile. Inventive genius has been applied to the problem of fixing the nitrogen of the air in some active compound and several different methods have developed; of these the present day operation is principally the formation of ammonia, and it appears from the book in hand about 722,000 tons are fixed annually as ammonia. It is well worth noting by Americans that of this amount 500,000 tons are fixed in Germany.

In the present book there is presented a comprehensive summary of the several methods now in use for nitrogen fixation. Descriptions are clear and detailed; all those interested in this very important problem will find set forth in very satisfactory form the present state of this industrial operation. Excellent illustrations of important plants add to the value of the essay. The theory and practice of each process is given. The user of the book will, therefore, be able to keep up to date in all phases of nitrogen fixation. The book is well printed, on good paper. Its low price will enable chemists generally to add it to their libraries.

HENRY LEFFMANN.

BIBLIOGRAPHY OF AËRONAUTICS, 1925. Prepared by the National Advisory Committee for Aëronautics. 189 pages, 8vo. Washington, Government Printing Office, 1928. Price, fifty cents.

This work covers the literature published from January 1 to December 31, 1925, and continues the work of the Smithsonian Institution issued as volume 55 of the Smithsonian Miscellaneous Collections, which covered the material published prior to June 30, 1909, and the work of the National Advisory Committee for Aëronautics as published in the Bibliography of Aëronautics for the years 1909 to 1916, 1917 to 1919, 1920 to 1921, 1922, 1923, and 1924.

As in the previous volumes, citations of the publications of all nations have been included in the languages in which these publications originally appeared. The arrangement is in dictionary form with author and subject entry and one alphabetical arrangement. Detail in the matter of subject reference has been omitted on account of the cost of presentation, but an attempt has been made to give sufficient cross references to facilitate research in special lines.

THE INDUSTRIAL CHEMISTRY OF THE FATS AND WAXES. By E. P. Hilditch, D.Sc. F.I.C. University of Liverpool. With introduction by E. F. Armstrong, D.Sc., F.R.S. xi–461 pages, 8vo. New York, D. Van Nostrand Company, Inc., 1927. Price, $6.

The literature concerning the fats and waxes (in the former term the oils are included) is now enormous, due to the great number of forms and the wide range of applications. The present work is limited to the industrial chemistry and therefore, the dietetic problems, which constitute in themselves a feature of great extent and complexity, are left out of consideration. It is interesting to note that the fundamental nature of the fats was elucidated more than a century ago, while the structural chemistry of the other two branches of the food triad, proteins and carbohydrates has only lately been approximately solved.

Dr. Armstrong, in his introductory note, says that the chemistry of the fats and waxes has received very little attention during the past twenty-five years, although they are substances of great importance. This may be due to the fact that their structure has been long known and attention has been directed to the study of their derivatives and to the modifications that may be brought about in them. The analytic problems have been the subject of a great deal of study, on account of the liability of them to adulteration and substitution. One of the derivatives, "glycerol," a name which is agreeable to see much used in the book, has acquired very high importance in many ways, but especially in the manufacture of explosives.

The book is not a textbook of chemical engineering, but is intended as a connecting link between an essay on the pure chemistry of the subject and the technology. In any work, however, it is now impossible to keep strictly to a special treatise and the text will frequently be carried over into associated fields. Such departures, however, are infrequent, occurring only when necessary, so that the book is especially constructed to serve the works-chemist rather than the consulting or commercial analyst. There is plenty of literature available for these latter.

The book was printed in Great Britain, and shows the rather heavy ink impression that usually characterizes British books, but it is excellent presswork. British reviewers sometimes complain of the lighter impression in American books, calling it "sepia" rather than black.

HENRY LEFFMANN.

THE STORY OF GEOLOGY. By Allan L. Benson. viii–297 pages, illustrations, 8vo. New York, Cosmopolitan Book Corporation, 1928.

The author of this book is known best as an active member of the socialist party, and as its candidate for president in 1916. Entering into literature as an author of a scientific treatise, the critic naturally scrutinizes the text with care. Geology, it is true, is hardly yet an exact science; there is much about it that is established, but from time to time, material changes take place in the attitude of its promoters. The fact is as Darwin pointed out and vividly expressed, the geologic record is so imperfect that great care must be taken in interpreting the information we have. It is well worth while for any one about to become interested in geology to read Darwin's chapter on "The imperfection of the geologic record."

At the very initiative of this book we meet with a rash statement that leads us to doubt its safety as a guide for those not familiar with the details of the science. We are told that "The earth under our feet and every star we can see with a glass, including the most distant star, are composed of the same substances." The statement is much too rash; it may be true, but we do not know if it is. We find that there is a good deal of similarity in the composition in the heavenly bodies, but analysis has not progressed nearly so far as to justify such a broad statement as the above, nor is it indeed important to consider such a question. Geology is a study of the earth, not of the universe, and there is no use going outside of the proper limits of the subject when the amount of material to be handled is very extensive.

This book, being intended for general reading, gives, of course, prominent expression of the attractive and striking features of the earth's surface. It is impossible in the limits allotted to the reviewer to consider all the details presented. The author accepts without question the community of descent between man and the apes, and the general succession of plant and animal forms as commonly taught. A large number of illustrations are given, all of which are of excellent quality and will serve to interest the reader and give information as to the many interesting sights on the face of the earth. There is, apart from the somewhat dogmatic attitude especially concerning the theory of evolution, an attitude which may be expected in one holding the author's views on the fundamental subjects, but there are nevertheless many interesting descriptions and explanations. Perhaps the book is strictly a discussion of "the face of the earth" rather than geology proper, but it is not necessary to cavil at such distinction. The book is well printed, of clear type, and as noted above, profusely illustrated.

HENRY LEFFMANN.

PHOTOCHEMICAL PROCESSES. By George B. Kistiakowsky, Princeton University. 270 pages, 8vo. American Chemical Society Monograph. New York, The Chemical Catalog Company, Inc., 1928. Price, $5.50.

The fact that light has a wide range of action has been known for many years and has been utilized in the many phases of photographic procedure now so abundantly featured in our everyday life. "You push the button and we do the rest" has given pleasure to millions of human beings both at home and in travel. That silver salts are especially affected by exposure to light was known to Glauber in the days when Pepys was writing his now famous (and in some respects infamous) diary, but many observers were inclined to believe that the result was due to heat or air. It was Heinrich Schulze, who in 1707 demonstrated that the darkening of silver salts was due to light alone. Since his time a vast industrial, artistic and scientific accumulation has been made, and active research is still going on, much of it financed by corporations manufacturing photographic supplies.

The present work is an inquiry into the phenomena of photochemistry from the standpoint of the quantum theory. A very large amount of data has been collected and set forth in a careful and scientific manner. The latest phases of the quantum theory are applied and the highly technical and, to most persons very abstruse principles are presented. One turns with interest to the discussion

of the most active storm-center of photographic physio-chemistry, namely, the latent image. Much printer's ink has been expended in arguing on this topic. The author leans to the theory originally propounded by Carey Lea and supported by Lüppo-Cramer, that the light acts by freeing a modicum of silver which is adsorbed on the silver halide. It has been proved that the action of light on silver halides results in the escape of a minute amount of the halogen, but this effect is in agreement with the view that a sub-halide is formed, as well as the other theory. It is remarkable that in all the discussions of the latent-image problem no account is taken of the fact that the whole of the halide may be removed by strong hypo, the plate thoroughly washed, appearing perfectly clear, and the image easily brought out in complete detail. Further in the reviewer's own experience, the latent image remains for years. The development after fixing is accomplished, as is well known, by the precipitation of metallic mercury instead of silver (although it is stated that silver also can be employed). The mercury evaporates in time but a reprecipitation can be made. There seems to be no discussion of this subject in this book although some space is given to the theories concerning the latent image. The photosensitiveness of mercurous iodide is also not mentioned, at least no reference is found in the index. This effect was pointed out in a German Journal in 1836, but not specially investigated. The present reviewer has made some experiments on the substance and it has seemed that by incorporating the iodide with gelatin and spreading the mixture on a plate, a more rapid effect is obtained. In this case the action probably depends on the liberation of an atom of mercury with formation of mercuric iodide. It s probable that all substances are somewhat affected by light.

HENRY LEFFMANN.

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Technical Drawing. A manual for evening classes and junior technical schools by George Edwin Draycott. 232 pages, illustrations, 12mo. London and New York, Oxford University Press, 1927, price $2.00.

Mechanics for Engineers, Statics and Kinetics, by Julian C. Smallwood and Frank W. Kouwenhoven. 185 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1928, price $2.50.

Photochemical Processes, by George B. Kistiakowsky. American Chemical Society Monograph Series. 270 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928, price $5.50.

The Physics of Crystals, by Abram F. Joffé. Edited by Leonard B. Loeb 198 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1928, price $3.00.

The Story of Geology, by Allan L. Benson. 300 pages, plates, 8vo. New York, Cosmopolitan Book Corporation, 1928.

The Industrial Chemistry of the Fats and Waxes, by T. P. Hilditch with an introduction by E. Frankland Armstrong. 461 pages, 8vo. New York, D. Van Nostrand Company, 1927, price $6.00.

Mechanochemistry and the Colloid Mill including practical applications of fine

dispersion, by Pierce M. Travis. 191 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928, price $4.00.

Fixation of Atmospheric Nitrogen, by Frank A. Ernst. Industrial Chemical Monographs. 154 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $2.50.

Bibliography of Aëronautics, 1925. National Advisory Committee for Aëronautics. 189 pages, 8vo. Washington, Government Printing Office, 1928, price fifty cents.

National Advisory Committee for Aëronautics. Technical notes. No. 289, Preliminary biplane tests in the variable density wind tunnel, by James M. Shoemaker, 15 pages, illustrations, quarto. No. 290, Welding of high chromium steels, by W. B. Miller. 13 pages, quarto. Washington, Committee, 1928.

CURRENT TOPICS.

Variations in the Quantity of Ozone Contained in the Atmosphere. JEAN CABANNES and JEAN DUFAY. (*Journal de Physique et le Radium*, Sept., 1927.) Fabry and Buisson have demonstrated the existence in the upper atmosphere of a layer of ozone which plays an important part in the absorption of solar radiation. Were all of this gas reduced to normal pressure and temperature it would form a layer about 3 mm. thick but this equivalent depth changes from day to day in an irregular way. At Oxford Dobson and Harrison have made a study of its variations. Their results based on observations made daily for ten months show that the local atmospheric pressure is closely connected with the variations and indicate the possibility of seasonal changes. One of the authors is carrying out at Montpellier, France, a similar series of observations that will finally give not only the thickness of the ozone layer but also its elevation.

Fortunately for the scientific patience of the writers of this paper they will not need to wait a decade or two until they have material accumulated by their own industry. They turn to the *Annals* of the Astrophysical Observatory of the Smithsonian Institution and there find ready to hand data on the transparency of the atmosphere above Mount Wilson in California and Calama in Chile. At Mount Wilson the observations were conducted from May to October or November while in Chile they were made in all seasons. For both stations the factors of transparency are listed for ten wave-lengths ranging from .35 to 1.60 μ. From these data on transparency it is possible by using a graphic method to derive the thickness of the equivalent ozone layer. This gas shows selective absorption for waves ranging in length from .48 to .65 or .70 μ. Upon the transparency of the air for wave-length .60, which lies close to the maximum absorption of ozone, the calculations of the thickness of the layer of this gas have been based. The error in the thickness amounts to about .06 cm. Over Mount Wilson the greatest thickness found was .45 cm. for May, 1908, and June, 1914, and the least .21 cm. for October, 1909. In general the thickness of the layergrows less from June to October. The average

thickness for May, obtained by using all records for that month from 1908 to 1920 inclusive, is .337 cm., and for the succeeding months it is: June, .375; July, .323; August, .313; September, .309; October, .303; November, .270 cm. These results agree well in their direction with those derived from the observations of Dobson and Harrison in Oxford.

The series at Calama extends only from July, 1918 to July, 1920. The greatest average thickness for any month was for July, 1918, .333 cm., and the least for May, 1919, .259 cm. The variation in value is much less than over Mount Wilson. There is some evidence of a seasonal variation of small amplitude at Calama but opposite to that which takes place at Mount Wilson. This difference is perhaps due to the two stations lying on opposite sides of the equator.

"The curve of annual means of the thickness of the ozone layer differs considerably from those which represent the annual values of the number of sunspots and the solar constant. There seems, however, to exist a certain relation between the thickness and solar activity, since there was little ozone during the years that preceded 1913, the year of minimum activity."

G. F. S.

Some Experiments with Sound Waves of High Frequency. S. R. HUMBY. (*Proc. Phys. Soc.*, Vol. 39, Pt. 5.) The late Lord Rayleigh used as a source of very short sound waves a bird call or whistle of high pitch. This is difficult to use in the absence of some means of applying a steady air pressure. "It was therefore decided to test the possibilities of a telephone receiver placed in the plate circuit of a three electrode vacuum tube which was producing oscillatory currents of the desired frequency. This arrangement has the great advantage that its frequency is regular and is under control. Also the intensity of the sound can be varied by means of a resistance box used to shunt the telephone earpiece." Frequencies between 4,000 and 16,000 were obtained. Effects were detected by a sensitive flame or occasionally by the ear. Some of the experiments will remind older members of The Franklin Institute of what they saw at a lecture by Walter LeConte Stevens in the '80's of last century. (He died only a short time ago.)

Data on the kinds and the use of sensitive flames are furnished. "The range of frequencies to which a jet responds

is often very small—in one case five separate responses were measured between 4,260 and 4,640." Reflection of sounds of high pitch was shown across a room by means of metal mirrors. The creeping of sound waves around a whispering gallery was demonstrated. When waves are reflected from a plane surface those going toward the surface interfere with those coming from it and stationary waves are formed. It is such stationary light-waves that Otto Wiener fixed photographically about 1889. Mr. Humby explored the space occupied by the standing waves by the use of two types of sensitive flames. One kind showed least disturbance at the loops and the other at both loops and nodes. "It is interesting to hear the variations of loudness of sound throughout a room when the note is switched on. The room is found to be filled with stationary nodes and loops, for, as the ear is moved, the sound swells out and diminishes in a fascinating way. It was found that with the one-valve circuit used and 60 to 200 volts high tension the stationary waves could be located by a sensitive flame at distances up to 15 feet from the source."

The waves were reflected at almost grazing incidence from a plane surface and came to interference with other waves travelling in almost the same direction that had not been reflected. A sensitive flame showed definitely this acoustical analogy of Lloyd's mirror fringes. In addition fringes from the interference of waves coming from two different sources and other interference effects like those due to the Heaviside layer obtained in wireless transmission were demonstrated. Diffraction effects were detected for a slit and for a straight edge as well as with a grating. With a zone plate marked alternate increases and decreases in intensity were found as the successive zones were removed.

G. F. S.

Rigidity and other Anomalies in Colloidal Solutions. EMIL HATSCHEK. (*Proc. Royal Inst. Great Britain*, No. 121.) Let a cube of elastic solid be held between two planes one of which is fixed while the other is moved to one side by a force acting parallel to itself. A shear is produced and owing to its rigidity the deformed solid will return to its original form upon the disappearance of the distorting force. If the cube is transparent and isotropic it becomes doubly refracting when sheared. This "accidental double refraction" affords a sensitive test for the existence of strains

and has been been used to study experimentally their extent and amount in cases that present difficulties to computation from theory. The modulus of rigidity, the force producing unit deformation on a cube of unit dimensions, is some tons per sq. cm. for steel and about 100 g./sq. cm. for gelatin jelly. All true solids possess rigidity but no normal liquid has it. If the space between two planes be filled with a liquid and a tangential force be applied to one plane, the other being fixed, the plane continues to move as long as the force acts. The force requisite to maintain the plane in motion is proportional to the area of the planes, to the velocity gradient between the fixed and the moving plane and to the coefficient of viscosity of the liquid, which is the force per unit area requisite to keep up unit velocity in the moving plane when the planes are a unit distance apart. In all liquids as in the case of molasses the viscosity increases in cold weather. The coefficient is remarkably independent of the velocity with which the moving plane travels. "The viscosity of water has been measured by a number of observers over a range of velocity gradient varying in the ratio of 1 to 10,000 and has been found quite constant."

A study of the viscosity of colloidal liquids made clear that they manifested bewildering anomalies. Order was introduced by the use of an instrument in which the liquid was contained between two coaxial cylinders one of which was rotated. The results for gelatine solutions are characteristic. As the angular velocity of the rotating cylinder increases the coefficient of viscosity grows less and tends to become constant for high velocities. At the smallest angular velocities the coefficient is two or three times as large as at high velocities. Many colloidal solutions of very different kinds have been studied and all show the same general comportment in respect to viscosity. To explain this marked divergence from the behavior of normal liquids Freundlich has suggested that colloidal solutions possess not only viscosity but also rigidity. "If this assumption is true, the liquid—to put the matter colloquially but picturesquely—will have to be stretched as well as sheared. It can be shown mathematically that the result will be what has been found experimentally, viz., that the viscosity decreases with increasing shear." The author has discovered a colloidal solution that displays rigidity to a remarkable extent—"a very dilute, about one-quarter per cent. solution of ammonium oleate, a soap familiar as material for soap

bubbles." The space between two cylinders was occupied by this solution. The pivoted inner cylinder was given a spin. Had it been surrounded by ordinary liquid it would have slowed up and finally come to rest, but with the ammonium oleate it came to rest and then started to rotate in the opposite direction somewhat as if it had been rotating in contact with a hollow cylinder of elastic rubber.

The moduli of rigidity of several colloidal solutions have been determined. All have no rigidity above 40° C. The viscosity of ammonium oleate is very temperamental changing constantly and over long periods of time. For colloidal solutions the moduli of rigidity are measured in milligrams per sq. cm. instead of in grams as is the case for gelatine jellies. Furthermore the modulus increases with the age of the solution. For example in the case of a solution of mercury-sulphosalicylic acid its modulus was eight times as great after 23 days as it was after 20 hours. In respect to the manifestation of rigidity the colloidal solutions examined showed much diversity. One shows rigidity if prepared hot but not if made at room temperature. Some, when heated to the temperature at which rigidity disappears regain upon cooling that property as it existed when the solution was old while others upon cooling behave as freshly made solutions. The phenomenon of double refraction occurs in most colloidal solutions.

G. F. S.

A New Mass-Spectrograph and the Whole Number Rule. F. W. ASTON. (*Proc. Roy. Soc.*, A 772.) The first mass-spectrograph, set up in the Cavendish Laboratory in 1919, could separate lines derived from masses differing by about 1 in 130. Its accuracy of measurement was 1 in 1,000 approximately. "These capabilities sufficed to determine with fair certainty the isotopic constitution of over 50 elements, and to demonstrate that, with the exception of hydrogen, the masses of all atoms could be expressed as integers on the scale O = 16 to one or two parts in a thousand." It was not till 1925 that this instrument which had rendered such iconoclastic service was dismantled. A need was felt for an instrument that would better separate the mass lines of the heavier elements and furnish more accurate information on divergences from integral mass numbers. A study of these divergences is of great value because they throw light on the structure of atomic nuclei. Costa in Paris, using an instrument with an accuracy of 1 in 3,000, in 1925 published excellent measurements on this matter. Now

Aston is ready to describe his perfected apparatus and to cite results obtained with it. The essential improvements consist in "doubling the angles of electric and magnetic deflection, and sharpening the lines by the use of finer slits placed further apart. The new instrument has five times the resolving power of the old one, far more than sufficient to separate the mass lines of the heaviest element known. Its accuracy is 1 in 10,000." The positively charged particles traversed a distance of 15 cm. in a magnetic field that could be extended to 20,400 gauss. At one stage in the development of the apparatus it gave discordant results even after months spent in an endeavor to make it work correctly. The solution of the difficulty was at last suggested by Sir Ernest Rutherford.

For the expression of masses the mass of the neutral oxygen atom has been taken as 16, as is commonly the case in chemical literature. While the existence of an isotope of oxygen has been suggested by Blackett's experiments on the disintegration of nitrogen nuclei under the impact of alpha rays, still up to the present the weight of evidence is on the side of the simplicity of oxygen. Of course if this element later is proved to be possessed of an isotope, a revision of masses established by the mass-spectroscope will be necessary. The mass of the electron is taken as .00054, when the oxygen atom is 16.

It is commonly believed that atoms have nothing else in their structure than electrons and protons, hydrogen nuclei. Since the proton has a positive charge and the electron an equal negative charge it follows from the neutrality of the atom that there are in it as many positive protons as negative electrons. The hydrogen atom consists of one proton with one electron. Hence the masses of all atoms should be integers, the mass of the hydrogen atom being unity. The first mass-spectrograph showed that this was not the case, even for individual isotopes. "The theoretical reason adduced for this failure of the additive law is that, inside the nucleus, the protons are packed so closely together that their electromagnetic fields interfere and a certain fraction of the combined mass is destroyed, whereas outside the nucleus the distances between the charges are too great for this to happen. The mass destroyed corresponds to energy released, analogous to the heat of formation of a chemical compound, the greater this is the more tightly are the component charges bound together and the more stable is the nucleus formed. It is for this reason that measurements of this loss of mass are of such fundamental importance, for by them we may learn something of the actual structure of the nucleus, the atomic number and the mass number being only concerned with

the numbers of protons and electrons employed in its formation." The "packing" fraction of the atom of an element is got by dividing the actual departure of its mass from a whole number by the mass number of the element. Since the mass number is the same as the number of protons in the atom the packing fraction expresses the "Gain or loss of mass per proton when the nuclear packing is changed from that of oxygen to that of the atom in question." It is expressed in parts per 10,000.

The results obtained with the new apparatus fall into two classes, additional information about isotopes and measurements of packing fractions. Under the first head sulphur has been proved to be triple consisting of atoms having masses of 32, 33 and 34. "S^{34} appears to be about three times as abundant as S^{33}; the two together amounting to about three per cent. of the whole." Calculation shows that this composition gives for the average atomic weight of the mixture a number close to the chemically determined atomic weight. Furthermore for tin no less than eleven isotopes have been discovered. Their mass numbers in the order of their intensities are 120, 118, 116, 124, 119, 117, 122, 121, 112, 114, 115. Two isotopes of xenon, hitherto in doubt, have been definitely shown to exist. Mercury presents six isotopes as follows, 198 (4), 199 (5), 200 (7), 201 (3), 202 (10) and 204 (2). The numbers in parentheses give the relative intensities. In all measurements of precision were made on 18 elements from hydrogen to mercury. This involved an examination of 51 types of atom, whose masses are now known to 1 or 2 in 10,000.

When the packing fractions are plotted against the mass numbers as abscissas it is seen that for all but light atoms they lie on a single curve. "Starting at hydrogen with a large positive packing fraction the curve drops rapidly, crosses the zero line in the region of mass number 20 and sinks to a minimum value of about -9 in the region of mass number 80. It then rises again and recrosses the zero line in the region 200. There is no marked periodicity." The packing fraction of hydrogen is (multiplied by 10^4) 77.8; of helium 5.4; of lithium 20.0. The largest negative value is for krypton, -9.4. G. F. S.

Sugar Cane Specialists Will Explore New Guinea for Disease-Resistant Varieties. Having come to the conclusion that New Guinea is the native home of sugar cane, the United States Department of Agriculture, has organized an expedition under the leadership of Dr. E. W. Brandes, sugar plant specialist, which will use an airplane in searching the unexplored wilds of the Island for disease-resistant cane varieties that may prove valuable to the industry in Louisiana and other parts of the South.

Doctor Brandes will sail from San Francisco April 12 accompanied by Dr. Jakob Jesweit who was formerly chief of sugar p ant breeding work in Java and now of the University of Wageningen, Holland; and Richard K. Peck who will pilot the plane. Peck acted as pilot for the Stirling Expedition to Dutch New Guinea under the Smithsonian Institution in 1926–27. These men will be joined at Honolulu by C. E. Pemberton, entomologist of the Hawaiian Sugar Plant Association Experiment Station, and proceed to Port Moresby, the base of the expedition on the southeast coast of New Guinea.

The plane, a Fairchild cabin type, will be furnished by B. G. Dahlberg, president of the Celotex Company, makers of synthetic lumber from sugar-cane bagasse, who is also interested in sugar-cane plantations in Florida and Louisiana. Equipped with pontoons for landing on rivers, lakes or other bodies of water, the plane will make possible the exploration of the interior portions of the Island otherwise inaccessible or difficult to reach. The study is expected to take from six to eight months. The Australian Government is coöperating to make the expedition possible and successful.

While the idea of such an expedition has been under consideration for the past six years or more, it has not been possible to bring it about until recently. Depression in the sugar-cane industry of Louisiana and other parts of the South resulting largely from the declining yields caused by mosaic and root diseases has given impetus to the project.

The most feasible method of improving the production of sugar cane in the South is by the use of varieties that are resistant or tolerant of these diseases. Some favorable results have already been accomplished by the introduction of several improved varieties developed at the Proefstation Oost Java, the experiment station maintained by private planters in Java. These varieties have given such satisfactory performance in tests during the past six years that specialists have been encouraged in the work. More than 170,000 acres were planted in Louisiana last fall with varieties recently introduced from Java.

Because sugar cane is propagated by cuttings instead of with seed, it will be necessary to adopt a method of keeping the collected canes in a growing condition until shipment can be made to the United States. A propagation garden will be established for the purpose at Port Moresby where newly collected specimens will be sent at intervals and planted. When the expedition is ready to return, cuttings will be taken from the propagating garden and shipped to Arlington Farm, Rosslyn, Va., for replanting in the department's sugar-cane greenhouses where they will be kept under observation for a year.

Under an improved method of propagating sugar cane introduced by Doctor Brandes, it is possible to increase the supply of cuttings from an original specimen about 20 times as rapidly as under the present commercial method. An illustration of the rapidity with which a commercial supply of planting material may be developed is seen in the fact that cuttings for the 170,000 acres planted last fall were produced from a few canes within four years.

Process for Manufacturing Genuine Maple Flavoring Product Devised. (U. S. Department of Agriculture, Press Service.) A process for manufacturing a true maple flavoring product, which when mixed with ordinary sugar sirup will make a reconstituted table sirup essentially the same as the commercial product, has been perfected by John W. Sale and J. B. Wilson, chemists of the Food, Drug and Insecticide Administration of the Department of Agriculture.

The process has been patented and has been dedicated to the public. Already one large manufacturer of flavoring products has taken steps to put the new flavor on the market.

The new flavor may be used by confectioners, bakers, ice cream manufacturers, and housewives, or by any others who use flavoring products. An excellent sirup can be made at home merely by adding the flavor in suitable proportions to a gallon of ordinary sugar sirup of proper density. The reconstituted table sirup will possess the delightful aroma and flavor of the original maple product.

All flavoring extracts on the market at the present time which purport to be "maple flavor" are synthetic products and even though they are harmless must be branded as "imitation maple" to meet the requirements of the Federal Food and Drugs Act. Most of them are made from a number of ingredients, the principal one in most formulas being fenugreek seed, an Old World plant of the bean family sometimes known as Greek hay seed. Other ingredients often used in making synthetic maple flavor are elm bark, celery seed, hickory bark, coffee, chicory, and vanillin.

No one has heretofore succeeded in preparing a genuine maple flavor—at least no flavor that is more concentrated than maple sugar. Maple sugar represents a maximum concentration of 1.3 parts maple sirup to 1 part maple sugar. All previous efforts toward the development of a true maple flavor have been along the lines of extracting the flavor itself. The process devised by Sale and Wilson, on the other hand, removes the sugar (sucrose) leaving nothing but the flavoring constituents. The sugar is precipitated by mixing a quantity of barium hydroxide with a

maple sugar solution such as maple sirup, partially concentrated maple sirup, maple sugar solution, or a combination of any two or more of these maple products. Subsequently, the excess barium reagent is completely eliminated.

The flavor thus recovered from 40 gallons of ordinary maple sirup can be so concentrated that it will be contained in 1 gallon of the concentrated flavoring product. Removal of the sugar also greatly enhances the keeping quality of the flavoring product, sugar being a highly fermentable substance. A by-product of the process is a sirup which is desirable for table or other uses.

Earth-Resistivity Measurements in the Copper Country, Michigan. W. J. ROONEY. (*Ter. Mag. and Atmos. Elect.*, Vol. 32, Nos. 3 and 4.) Much attention has recently been given to the connection between the physical properties of the earth's crust and its geological structure for the purpose of learning to locate oil, ore and mineral deposits. In the present research the Department of Terrestrial Magnetism and the Michigan College of Mines coöperated in studying the resistivity of the earth in the Upper Peninsula, where the geological structure is well known.

Wenner has shown that if four contacts equally spaced in a straight line are made with a large mass of a substance and if an electric current flow from one end contact through the mass to the other end contact then the potential between the inner pair of contacts divided by the total current is proportional to the resistivity of the material. The resistivity can be computed if the difference of potential current and distance from one contact point to the next be known. As the distance between contacts is increased the current penetrates more deeply into the earth and any change in the character of the material traversed by the current is revealed by a corresponding change in the resistivity obtained by applying the formula. It is the material near to the line of contacts that has the preponderating effect in determining the mean resistivity. Material as far away as the distance between adjacent contacts has little influence on the resultant resistivity.

In a series of measurements made near a drill hole so that geological structure might be known the average resistivity of a cm. cube in ohms was 5750 when the steel rods forming the contacts were driven in the earth 10 ft. apart. As the distance from one rod to the next increased the resistivity grew rapidly becoming a maximum of 82,000 ohms for a separation of 25 ft. This was interpreted to mean that at first the current was practically confined to the humus laden soil at the surface. When the rods were farther apart it penetrated to the underlying coarse drift. A further sepa-

ration to 50 ft. brought the resistivity down to 36,500 while still further separation caused it to rise slowly, becoming 81,800 when the rods were 200 ft. from one another. It is clear that beyond 25 ft. the current penetrated into a layer of small resistance, no doubt underground water. Beyond 50 ft. rock showed its presence by the increase in resistivity. Drill hole records located the rock 64 ft. below the surface.

By the same method the resistivity of several kinds of rock was measured. In general trap and other volcanic rocks had a resistivity from 5 to 20 times as great as that of porous sedimentary varieties. Very strange results were got by applying the method to a block of Calumet and Hecla conglomerate about 20 ft. long. These were however consistent with the presence of copper in the mass.

G. F. S.

The Optical Analogue of the Compton Effect. C. V. RAMAN and K. S. KRISHNAN. (*Nature*, May 5, 1928.) Two photographs are reproduced. The first shows the spectrum of light from a quartz mercury vapor lamp and the second that of the light scattered from toluene, the incident light being that of the first photograph. The second print shows several lines that are absent from the first. By the use of light filters it was found that the occurrence of these additional lines was dependent upon the presence in the incident light of certain lines or groups of lines having shorter wave-length. "Thus the analogy with the Compton effect becomes clear, except that we are dealing with shifts of wave-length far larger than those met with in the X-ray region." It is suggested "that an incident quantum of radiation may be scattered by the molecules of a fluid either as a whole or in part, in the former case giving the original wave-length, and in the latter case an increased wave-length." G. F. S.

The History of the Franklin Tree, Franklinia alatamaha. EDGAR T. WHERRY. (*Jour., Washington Acad. Sciences*, March 19, 1928.) "The Franklin tree is one of the few members of the Camellia family (Ternstrœmiaceæ or Theaceæ) which have survived the climatic and geographic changes of late Tertiary and Quaternary times on the North American continent. Considerable interest has been shown in this plant during recent years; largely owing to the fact that it has apporently become extinct in its native place, and is preserved only in cultivation." John Bartram discovered it near Fort Barrington, Georgia, in 1765. Eight years later his son William Bartram, who had accompanied his father at

the time of this visit, went back to the spot and, according to his cousin Humphrey Marshall in his Arbustum Americanum, 1785, "had the pleasing prospect of beholding it in its native soil, possessed with all its floral charms; and bearing ripe seeds at the same time; some of which he collected and brought home, and raised several plants therefrom, which in four years' time flowered. William Bartram has chosen to honor it with the name of that patron of sciences, and truly great and distinguished character, Dr. Benjamin Franklin. The trivial name is added from the river, where alone it has been observed to grow naturally." William Bartram testifies to its rarity in nature thus: "We (he and his father) never saw it grow in any other place, nor have I ever seen it growing wild in all my travels, from Pennsylvania to Point Coupè, on the banks of the Mississippi, which must be allowed a very singular and unaccountable circumstance." In 1790 a nephew of Humphrey Marshall found the tree still growing wild at the original spot. Though careful and repeated search has been made by competent persons no one has found it growing wild since 1790. There is reason to believe that at least part of the Georgia colony of Franklin trees was shipped to England and a fire may have finished the destruction. That the species persists at all is due to the survival of one specimen that Bartram transplanted to an acid part of his famous garden in Philadelphia. Nurserymen obtained plants but few succeeded until it was found that the tree does best in acid soil. Dr. F. V. Coville, who made this discovery, now has thriving trees in the nursery in Whitesbog, N. J. The tree is nearly sterile to its own pollen. "There are several specimens in old Philadelphia gardens, all apparently derived from the Bartram tree. One or two nurseries near New York City have supplied plants to estates in that vicinity, but they obtained their stock in the first place from Thomas Meehan and Sons, who utilized Bartram's garden as their original source of cuttings. The single tree at Chevy Chase Circle, Washington, D. C., also came from Meehan's. The hope may be expressed, however, that some day a descendant from another ancestor will be discovered, and the cross-pollination and production of seedlings in quantity may then become possible, representing the final step in the permanent preservation of this interesting plant."

G. F. S.

The Use of Photo-Electric Cells for the Photometry of Electric Lamps. T. H. HARRISON. (*Trans. of the Optical Soc.*, Vol. 28, No. 4.) Both sodium and rubidium cells were used in making a comparison between the accuracy attainable by their use and that

got by using the human eye. In four general comparisons the eye was found to be the less accurate. In spherical color matching the cells were five times as accurate, in mean spherical intensity measurements two times, in directional color matching five times and in directional intensity measurements nearly twice as accurate as the eye.

G. F. S.

The Problem of Artificial Production of Diamonds. C. H. D. (*Nature*, May 19, 1928.) It is easy to convert diamonds into graphite at high temperatures but the greatest difficulties bar the path of the converse transformation. Little is to be learned in regard to the genesis of diamonds from the way they occur in nature, but the assumption has often been made that they have been formed under high pressure. Henri Moissan's experiments were directed by this belief. He melted pure iron with sugar charcoal by the electric arc and cooled the molten mass rapidly in cold water, relying upon the contraction of the iron for the development of high pressures. Acids, oxidizing mixtures and fused potassium hydrogen fluoride dissolved the iron and, presumably, all minerals save diamond. There remained tiny crystals identified as diamonds by their optical properties and by giving CO_2 on combustion. Silver was used in the place of iron with the same final results. Crookes obtained similar crystals from the explosion of cordite in a bomb where the pressure rose to 8,000 atmospheres.

Sir Charles Parsons, whose presence at the Centenary of The Franklin Institute in 1924 is recalled with great pleasure, in his Bakerian lecture in 1918 reported the results of his own extensive series of experiments. He found that carbon, either liquefied or vaporized at a pressure of 15,000 atmospheres failed to crystallize as Crookes and Moissan held that it would, that in Moissan's work great pressure was not caused by quenching molten iron, that the application of a pressure of 100 tons per sq. in. to the molten iron resulted in the production of a smaller mass of crystals than in quenching, and, finally, that the presence in the iron of magnesium, chromium, silicon and aluminium as impurities augments the crystal residue which scarcely existed when commercially pure iron was used. He recognized the extreme difficulty of identifying the crystals left after treatment. Because of the uncertainties that adhere to Moissan's results, H. M. Duncan, who worked with Parsons, has made a study of the analytical methods involved. Spinels are hard to dissolve, he asserts, and optically may easily be taken for diamonds if they are small. "Whenever Moissan's experiments with cast iron have been repeated, although many particles

resembling diamond in appearance have been obtained, they have never stood the Combustion test.", Parsons and Duncan have repeated the work of others who believed themselves successful in producing diamonds, but in no instance could they confirm the results of their predecessors. "The conclusion seems inevitable that diamonds have not yet been produced in the laboratory, and that investigators have been misled into regarding as diamonds various transparent singly-refracting minerals which happen to be very resistant to chemical reagents." G. F. S.

A New Radiation. C. V. Raman. (*Indian J. Physics*, Vol. 2, Pt. 3.) This address was delivered to the South Indian Science Association on March 16, 1928 at Bangalore.

Atoms and molecules may be made to emit light by heating or by bombarding with streams of electrons. Such radiation is designated primary. When under the influence of strong illumination substances are made to emit radiation it is called secondary. The light given out by fluorescent materials is of this kind. In the same category belongs scattered light which gives the blue color to the sky and to the deep sea and causes the opalescent effect in large bodies of clear ice. This scattering effect occurs in solids, liquids and gases.

During the past seven years much work has been done in Prof. Raman's laboratory in Calcutta upon the scattering of light by transparent media. He says "One important outcome of our researches has been to show that while light-scattering is in one sense a molecular phenomenon, in another sense it is a bulk-effect having a thermal origin. It is the thermal agitation of the molecules which causes them to be distributed and oriented in space with incomplete regularity, and it is the local fluctuations in the medium thus arising which give rise to optical heterogeneity and consequent diffusion of light. The subject of light-scattering is thus a meeting ground for thermodynamics, molecular physics and the wave-theory of radiation." The investigations of Ramanathan, Krishnan and Venkateswaren brought to light some significant polarization effects which led early in 1928 to a very important observation made by Raman and Krishnan. They had at their disposal a strong beam of sunlight concentrated by using a seven-inch telescope objective with a short focus lens. The resulting beam traversed a blue-violet filter and then entered a bulb containing a liquid that had been distilled in vacuo. They had a green glass filter that transmitted none of the light that came through the other filter. When both were placed in the path of the incident beam no light came from the liquid because no light reached it. If, however, the

first filter was in the incident beam while the other was held between the liquid and the observer the opalescent path of the beam in the liquid remained still visible, though it was not as bright as it appeared upon removing the filter. Eighty liquids were examined and all manifested this effect. The speaker demonstrated the phenomenon to his audience with toluene. It is true that the newly observed effect resembles fluorescence but it differs from it in this that the light from the liquid is distinctly polarized. Ice, amorphous solids, organic vapors, CO_2 and N_2O, all display the effect.

The spectrum of the light originating in the liquid benzene was studied. Light from a quartz mercury lamp was sent through a filter that cut out all wave-lengths longer than the indigo line 4358 A.U. The spectrum of the liquid excited by this radiation of short wave-length was photographed as well as that of the incident radiation. The spectrogram from the liquid shows several sharp lines not found in the light before it reached the benzene. "It is thus clear that each line in the incident spectrum gives rise to at least two lines in the scattered spectrum, one in the original or unmodified position, and a second in a position of longer wave-length. There is thus a striking analogy with the Compton effect in the X-ray region. The most pressing question is, how is the modified scattered radiation, as we may call it, generated by the molecules of the liquid? As a tentative explanation we may adopt the language of the quantum theory, and say that the incident quantum of radiation is partially absorbed by the molecule, and that the unabsorbed part is scattered." G. F. S.

Optical Exhibition, Washington. The Optical Society of America and the Bureau of Standards will conduct an exhibition of optical instruments and optical products in the buildings of the Bureau on October 31, November 1, 2, 3. It will be open daily during the sessions of this annual meeting of the Optical Society and during one evening session.

New instruments and apparatus of especial design will be included. All American-made instruments or products in which the application of optical principles is an important part in design, construction or use, are eligible. The following partial classification will indicate the character and scope of the exhibition: optical and colored glasses, fused silica, optical components, spectacle lenses, ophthalmic instruments, binoculars, microscopes, photographic apparatus, colored photographic processes, motion picture apparatus, astronomical instruments, interferometers, spectral apparatus, metrological instruments, surveying and nautical instruments,

search-lights, telescopic gunsights, photometric apparatus, optical pyrometers, colorimetric instruments, vacuum discharge tubes, special systems of illumination, etc.

Intending exhibitors should communicate with Mr. I. C. Gardner, Chairman, Committee on Optical Instrument Exhibit, Bureau of Standards, Washington, D. C.

World Congress on Illumination. Immediately following the meeting of the Illuminating Engineering Society which will open in Toronto on September 17 next, there will be held at Saranac Inn, New York, the first international congress on illumination. Foreign delegates to this congress will meet in New York about September 5.

Members of the Illuminating Engineering Society will have an opportunity to accompany the foreign visitors on their tour of inspection of lighting installations, laboratories and manufacturing establishments devoted to lighting. The meetings of the Congress will be held on September 22 to 28 inclusive and papers will be presented by leading authorities on scientific and practical subjects of outstanding interest.

International symposia on residence lighting, show-window lighting, lighting for aviation and the status of lighting education have been arranged.

Open committee meetings for the discussion of topics assigned to international committees have aroused the greatest interest throughout the lighting industry. Sessions are scheduled to be held under the auspices of various International technical committees covering Automobile Headlighting, directed by Dr. Clayton H. Sharp, of the United States Committee; Daylight Illumination, by the British Committee; Factory and School Lighting, by U. S. National Committee; Research on Glare, under the secretariat of the Italian National Committee; and Street Lighting, directed by W. Wissman, of Germany.

The International Commission on Illumination, which was founded in 1900 as the International Photometric Commission, has been the international medium for conference and standardization in illumination matters, and has been responsible for many important international understandings.

Fixed Nitrogen in Competition with Chilian Nitrate. (Press Service U. S. Department of Agriculture.) For many years the extensive and unique deposits of sodium nitrate in Chile have enabled that country to determine the price of the material. The other natural sources of nitrogen compounds have not been able to compete. The progress of methods for the fixation of atmospheric

nitrogen now threatens the Chilian monopoly, and may have a serious effect on the revenues of the government which has relied very largely upon taxes on the product. The first efforts at nitrogen fixation were with the arc; later the cyanamide process was developed. Both these however, require large electrical power and consequently are not economically operated except where natural conditions such as water power are favorable.

Recently the development of the direct synthetic process for making ammonia by combination of nitrogen and hydrogen under the influence of a catalyst has reached such a point that it is now clearly evident that the Chilian monopoly will before long be seriously challenged, and the major nations will be entirely self-reliant for their supplies of nitrogen compounds. Germany was the first to operate this method on a very large scale but other nations are now entering the field actively. It is gratifying to note that United States has several large plants under operation by private companies. H. L.

Sodium Alum. Sodium alum (the double sulphate of sodium and aluminium) was discovered by Gehlen in 1815; Zellner, in 1816, published the results of his elaborate study of this double salt; he determined its percentage composition, and gave it its name, Natrumalaun or sodium alum. Henry Leffmann and Lester W. Strock (*Bull. Wagner Free Inst. Science*, 1928, 3, 19–22) have studied this alum anew. Crystals are not readily obtained on cooling the boiling saturated, aqueous solution, but deposit on evaporation at a moderate temperature, or on spontaneous evaporation at room temperature. The crystals are isotropic to polarized light, clear, and brilliant. Octahedra have been obtained measuring approximately one centimeter on the edge. The usual form is the octahedron truncated by the cube. Cubes have been obtained, also a monoclinic crystalline form. The crystals effloresce readily; exposure to the air for several minutes suffices to develop a white, powdery material on the edges of the crystals. The paper is illustrated with a picture of the crystals. J. S. H.

Vitamin B. HERBERT M. EVANS AND GEORGE O. BURR of the University of California (*Jour. Biol. Chem.*, 1928, 77, 231–240) find that the vitamin hitherto designated as water-soluble B actually consists of two distinct vitamins, one of which is antineuritic while the other is purely a promoter of growth. They used rats as experimental animals. The dilute alcoholic extract of white rice polishings, known as tikitiki, is almost lacking in the growth-promoting vitamin, but is rich in the antinuritic vitamin which

prevents beriberi in man and polyneuritis in animals. Commercial casein and commercial corn-starch lack the antineuritic vitamin, but contain the growth-promoting vitamin. Both vitamins are present in yeast. They are now designated, respectively, as antineuritic vitamin B, and purely growth-promoting vitamin B.

J. H. S.

Flavor and Odor of Milk. C. J. BABCOCK (Certified Milk Conferences, 1927, 122–126) has studied the influence of various feeds upon the flavor and odor of milk. In one series of experiments, the feed was given to the cows one hour prior to milking. Green alfalfa, cabbage, turnips, rape, kale, and silage made from corn, alfalfa, sweet clover, and soy beans exerted a marked influence on both the flavor and the odor of the milk. Green rye, cowpeas, Irish potatoes, carrots, and dried beet pulp exerted a slight influence, while green corn, oats, peas, soy beans, pumpkins, and sugar beets had no influence. The influence of large amounts of cabbage was apparent twelve hours after feeding, that of the bitter weed, *Helinium tenuifolium*, for twenty-seven hours after feeding. As a rule, the objectionable odor and flavor were more pronounced in the cream than in the skimmed milk; however, in the case of bitter weed, they were more apparent in the skimmed milk; they were usually removed to a marked extent by aëration.

The influence of garlic was studied in some detail. The garlic odor and flavor appeared in the milk in one minute after cows had eaten one-half pound of garlic tops, was still present at the end of four hours, and had almost disappeared at the end of seven hours. They were present in milk taken two minutes after cows had been made to inhale the odor of garlic for ten minutes, but had practically disappeared when milk was drawn an hour and a half after the inhalation. Cows were fed two pounds of garlic tops; their blood had a perceptible garlic odor at the end of thirty minutes, and a still more marked garlic odor at the end of forty-five minutes.

The entire group of experiments demonstrated that the odor and flavor of the feed may be absorbed from either the lungs or the digestive tract, pass into the blood, and be imparted to the milk.

J. S. H.

Quality of the Surface Waters of New Jersey. According to W. D. COLLINS AND C. S. HOWARD (U. S. Geol. Survey Water Supply Paper 596E, 89–119, 1927) the surface waters of New Jersey are fairly clear, not highly colored, and of a low mineral content. The predominating constituents are calcium, magnesium, and bicarbonate ions, with lesser amounts of sodium, chloride, and

sulphate ions. The chloride and sulphate content may be increased by sewage and industrial wastes. The waters in the southern part of the state are softer but more highly colored than those in the northern part of the state. The surface waters are one of the most valuable natural resources of the state. Results are given of the analyses of 121 samples of surface waters; the analyses deal more especially with mineral constituents; however the total dissolved solids, chlorides, and nitrates also have sanitary significance.

J. S. H.

Fossils of the Pocono Formation. GEORGE H. GIRTY (U. S. Geol. Survey, Professional Paper 150E, 111–127, 1928) has examined and described the fauna of the Pocono formation in the Broad Top Coal Field of Pennsylvania. The fossils came from four localities, and included twenty species of marine invertebrates; brachiopods predominated. Each genus is represented by but a single species. While of Carboniferous age, yet this formation lacks certain highly characteristic genera of that age. J. S. H.

Preparation of Reagent Alcohol. SOL KICZALES (*Ind. Eng. Chem.*, 1928, **20**, 493) has devised the following procedure for the preparation of aldehyde-free reagent alcohol. To each liter of alcohol are added, first a solution of 2.5 or 3 grams of lead acetate in 5 cc. of distilled water, then a solution of 5 grams of potassium hydroxide in 25 cc. of warm alcohol. The solution of lead acetate is added with thorough mixing. The solution of potassium hydroxide is added slowly without stirring; one hour later the liquid is thoroughly mixed, then permitted to stand over night. A precipitate forms, which is an addition product of lead oxide with the aldehyde originally present in the alcohol. The precipitate is removed by filtration; and the filtrate is distilled to obtain aldehyde-free alcohol, which is used in the preparation of alcoholic potash reagent. This procedure is more efficient and more economical than that based on the use of silver oxide. J. S. H.

New Reagent for Potassium. RUFUS D. REED AND JAMES R. WITHROW (*Jour. Am. Chem. Soc.*, 1928, **50**, 1515–1522) recommend the use of zirconium sulphate as a reagent for the detection of potassium. The aqueous solution of zirconium sulphate was approximately saturated at room temperature; it was prepared by stirring the powdered salt with distilled water for four hours, standing over night, and filtering, and contained 20.96 grams of the salt per 100 cc. In order to detect potassium, a definite volume of the unknown solution was mixed with an equal volume of the

zirconium sulphate solution. If a precipitate of potassium zirconium sulphate did not form at room temperature, the solution was cooled in ice water. With small amounts of potassium, a blank experiment was also made, using zirconium sulphate plus either water (in the absence of sodium in the test proper) or sodium sulphate solution (when sodium was present in the test proper). This procedure was sufficiently delicate to detect 0.5 milligram of potassium present as the 0.0068 molar solution of potassium sulphate, and to detect 1.76 milligrams of potassium in the presence of sodium. Dilution of the zirconium sulphate solution to one-half strength had practically no influence upon its sensitiveness for potassium in the absence of sodium, and increased its sensitiveness to 0.7 milligram of potassium in the presence of sodium. Large amounts of sodium sulphate retarded this reaction for potassium in concentrated solutions, but had little or no influence when the potassium was present in small amounts. J. S. H.

Electro-Deposited Copper. ARTHUR KENNETH GRAHAM (Thesis, University of Pennsylvania, 1927, 1–21) has studied the influence of various variable factors upon the structure of electro-deposited copper, when the electrolyte is an acid solution of cupric sulphate. The base metal was found to influence the structure of the deposited copper. J. S. H.

Biological Test of Glass Substitutes. R. L. COCHRAN AND H. A. BITTENBENDER (Iowa State Coll. Agric. and Mechanic Arts, Agric. Exp. Station Bull. 246, 168–184, 1928) have tested five commercial glass substitutes for their permeability to the biologically active ultra-violet rays. Growing chickens served as experimental animals. The glass substitutes were used as the top and front of boxes in which the chickens were exposed to the sunshine. Prevention of the condition known as leg weakness was a measure of the permeability of the substitute to the beneficial ultra violet rays. Physical laboratory tests showed that the substitutes transmitted from 4.0 to 30.7 per cent. of the ultra violet rays of sunlight, and from 0.0 to 26.1 per cent. of the ultra violet rays of the quartz mercury vapor lamp. Four of the substitutes transmitted sufficient of the active rays to prevent the development of leg weakness; the fifth substitute did not present this condition, the physical tests showed that this substitute transmitted less ultra violet of solar origin than did window glass. When the ration was well balanced with respect to its mineral constituents, leg weakness was prevented by a small amount of ultra violet light, *e.g.*, an average daily exposure to sunlight for 55 minutes during the winter months, provided

the glass substitutes transmitted at least 12 per cent. of the beneficial rays. Lack of these rays could be compensated by the addition of 2 per cent. of cod liver oil to the ration. The recommendation is made that, whenever glass substitutes are used, they always be placed in a vertical position. J. S. H.

Radio Communication on Moving Trains.—The utility of radio in maintaining communication for signaling and other purposes between the engine and caboose of long freight trains was submitted to the test of a practical trial, under actual working conditions, by the Pennsylvania Railroad. For this purpose a demonstration run with an experimentally radio-equipped train was made on June 26, from Altoona, Pa., to Pittsburgh, Pa.

The test was witnessed and the results recorded by officers representing various departments of the Pennsylvania Railroad, and the Westinghouse Electric and Manufacturing Company, by which the signal equipment was made. There were also present officers of other trunk line railroads.

The apparatus required for the tests was installed in a Pennsylvania Railroad Class I–1s locomotive, such as is used in the heaviest freight service, which headed the train, and in an all-steel cabin car which was at its rear.

The radio system which was used was devised to maintain both telephonic communication and code signaling. Transmitters and receivers, with loud speakers, are provided in both the locomotive and caboose. The effective range of the system much exceeds the length of any freight trains ever operated.

The Horse Shoe Curve territory of the Alleghenies was chosen for the experiment because the run provided a number of situations in which the use of radio communication between the engine and caboose should prove most effective.

Among the advantages of radio signaling is the fact that after the flagman has been dropped back and is recalled, the train may be started instantly when he reaches the caboose. When the train pulls into a siding the engineman may be notified as soon as the caboose has cleared the switch. If a standing train has to be parted at a grade crossing to allow highway traffic to pass, the engineman may be advised by radio to back up so as to permit uncoupling at the right point, then to proceed, and then to stop. At any time a member of the crew at the rear of the train can immediately notify the engineman should any trouble or difficulty be observed.

It is expected that the results of these tests will enable the railroad officials to form a more accurate opinion than has been heretofore possible as to the value of radio communication under

all conditions of service. The radio engineers who have devised the new signaling system believe that sets on passing trains should not interfere with each other, as each will operate on a wave-length of its own.

Measurement of the True Specific Heat of Nickel by a Direct Electrical Method. MISS CH. LAPP. (*Comptes Rendus*, April 23, 1928.) Measurements were made on pure nickel for temperatures ranging from − 175° to + 460°. A nickel wire is put in a furnace whose temperature is kept uniform. For a part of a minute an electric current is sent through the wire the temperature of which is thereby raised one or two degrees. The temperature is obtained from a thermoelectric couple and the time is registered by a chronograph. From the use of these data supplemented by the energy furnished by the current to the wire it is possible to compute the specific heats at different temperatures.

Temperature	−175°	+10°	339°	350°	352.2°	352.8°	353.8°	360°	460°
Specific Heat	.055	.1062	.147	.1541	.156	.1577	.1577	.1278	.1288

It will be noticed that the value decreases very suddenly from 353° to 360°. This corresponds to the change of nickel from the ferromagnetic to the paramagnetic state. From a study of the specific heats this temperature of change, the Curie point, is put at 356.1° whereas from magnetic measurements it has been located at 357.6°.

G. F. S.

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